GUNS,

GERMS AND STEEL

THE FATES OF HUMAN SOCIETIES

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Once again, we can easily push this question back one step further, by drawing on written histories and archaeological discoveries. Until the end of the last Ice Age, around 11,000 B.C., all peoples on all continents were still hunter-gatherers. Different rates of development on different continents, from 11,000 B.C. to A.D. 1500, were what led to the technological and political inequalities of A.D. 1500. While Aboriginal Australians and many Native Americans remained hunter-gatherers, most of Eurasia and much of the Americas and sub-Saharan Africa gradually developed agriculture, herding, metallurgy, and complex political organization. Parts of Eurasia, and one area of the Americas, independently developed writing as well. However, each of these new developments appeared earlier in Eurasia than elsewhere. For instance, the mass production of bronze tools, which was just beginning in the South American Andes in the centuries before A.D. 1500, was already established in parts of Eurasia over 4,000 years earlier. The stone technology of the Tasmanians, when first encountered by European explorers in A.D. 1642, was simpler than that prevalent in parts of Upper Paleolithic Europe tens of thousands of years earlier.

Thus, we can finally rephrase the question about the modern world's inequalities as follows: why did human development proceed at such different rates on different continents? Those disparate rates constitute history's broadest pattern and my book's subject.

While this book is thus ultimately about history and prehistory, its subject is not of just academic interest but also of overwhelming practical and political importance. The history of interactions among disparate peoples is what shaped the modern world through conquest, epidemics, and genocide. Those collisions created reverberations that have still not died down after many centuries, and that are actively continuing in some of the world's most troubled areas today.

For example, much of Africa is still struggling with its legacies from recent colonialism. In other regions—including much of Central America, Mexico, Peru, New Caledonia, the former Soviet Union, and parts of Indonesia—civil unrest or guerrilla warfare pits still-numerous indigenous populations against governments dominated by descendants of invading conquerors. Many other indigenous populations—such as native Hawaiians, Aboriginal Australians, native Siberians, and Indians in the United States, Canada, Brazil, Argentina, and Chile—became so reduced in numbers by genocide and disease that they are now greatly outnumbered by the descendants of invaders. Although thus incapable of mounting a civil war, they are nevertheless increasingly asserting their rights.

In addition to these current political and economic reverberations of past collisions among peoples, there are current linguistic reverberations—especially the impending disappearance of most of the modern world's 6,000 surviving languages, becoming replaced by English, Chinese, Russian, and a few other languages whose numbers of speakers have increased enormously in recent centuries. All these problems of the modern world result from the different historical trajectories implicit in Yali's question.

CHAPTER 3

COLLISION AT CAJAMARCA

THE BIGGEST POPULATION SHIFT OF MODERN TIMES HAS been the colonization of the New World by Europeans, and the resulting conquest, numerical reduction, or complete disappearance of most groups of Native Americans (American Indians). As I explained in Chapter 1, the New World was initially colonized around or before 11,000 B.c. by way of Alaska, the Bering Strait, and Siberia. Complex agricultural societies gradually arose in the Americas far to the south of that entry route, developing in complete isolation from the emerging complex societies of the Old World. After that initial colonization from Asia, the sole well-attested further contacts between the New World and Asia involved only hunter-gatherers living on opposite sides of the Bering Strait, plus an inferred transpacific voyage that introduced the sweet potato from South America to Polynesia.

As for contacts of New World peoples with Europe, the sole early ones involved the Norse who occupied Greenland in very small numbers between A.D. 986 and about 1500. But those Norse visits had no discernible impact on Native American societies. Instead, for practical purposes the collision of advanced Old World and New World societies began abruptly in A.D. 1492, with Christopher Columbus's "discovery" of Caribbean islands densely populated by Native Americans.

The most dramatic moment in subsequent European-Native American relations was the first encounter between the Inca emperor Atahuallpa and the Spanish conquistador Francisco Pizarro at the Peruvian highland town of Cajamarca on November 16, 1532. Atahuallpa was absolute monarch of the largest and most advanced state in the New World, while Pizarro represented the Holy Roman Emperor Charles V (also known as King Charles I of Spain), monarch of the most powerful state in Europe. Pizarro, leading a ragtag group of 168 Spanish soldiers, was in unfamiliar terrain, ignorant of the local inhabitants, completely out of touch with the nearest Spaniards (1,000 miles to the north in Panama) and far beyond the reach of timely reinforcements. Atahuallpa was in the middle of his own empire of millions of subjects and immediately surrounded by his army of 80,000 soldiers, recently victorious in a war with other Indians. Nevertheless, Pizarro captured Atahuallpa within a few minutes after the two leaders first set eyes on each other. Pizarro proceeded to hold his prisoner for eight months, while extracting history's largest ransom in return for a promise to free him. After the ransom—enough gold to fill a room 22 feet long by 17 feet wide to a height of over 8 feet—was delivered, Pizarro reneged on his promise and executed Atahuallpa.

Atahuallpa's capture was decisive for the European conquest of the Inca Empire. Although the Spaniards' superior weapons would have assured an ultimate Spanish victory in any case, the capture made the conquest quicker and infinitely easier. Atahuallpa was revered by the Incas as a sun-god and exercised absolute authority over his subjects, who obeyed even the orders he issued from captivity. The months until his death gave Pizarro time to dispatch exploring parties unmolested to other parts of the Inca Empire, and to send for reinforcements from Panama. When fighting between Spaniards and Incas finally did commence after Atahuallpa's execution, the Spanish forces were more formidable.

Thus, Atahuallpa's capture interests us specifically as marking the decisive moment in the greatest collision of modern history. But it is also of more general interest, because the factors that resulted in Pizarro's seizing Atahuallpa were essentially the same ones that determined the outcome of many similar collisions between colonizers and native peoples elsewhere in the modern world. Hence Atahuallpa's capture offers us a broad window onto world history.

WHAT UNFOLDED THAT day at Cajamarca is well known, because it was recorded in writing by many of the Spanish participants. To get a flavor of those events, let us relive them by weaving together excerpts from eyewitness accounts by six of Pizarro's companions, including his brothers Hernando and Pedro:

"The prudence, fortitude, military discipline, labors, perilous navigations, and battles of the Spaniards—vassals of the most invincible Emperor of the Roman Catholic Empire, our natural King and Lord—will cause joy to the faithful and terror to the infidels. For this reason, and for the glory of God our Lord and for the service of the Catholic Imperial Majesty, it has seemed good to me to write this narrative, and to send it to Your Majesty, that all may have a knowledge of what is here related. It will be to the glory of God, because they have conquered and brought to our holy Catholic Faith so vast a number of heathens, aided by His holy guidance. It will be to the honor of our Emperor because, by reason of his great power and good fortune, such events happened in his time. It will give joy to the faithful that such battles have been won, such provinces discovered and conquered, such riches brought home for the King and for themselves; and that such terror has been spread among the infidels, such admiration excited in all mankind.

"For when, either in ancient or modern times, have such great exploits been achieved by so few against so many, over so many climes, across so many seas, over such distances by land, to subdue the unseen and unknown? Whose deeds can be compared with those of Spain? Our Spaniards, being few in number, never having more than 200 or 300 men together, and sometimes only 100 and even fewer, have, in our times, conquered more territory than has ever been known before, or than all the faithful and infidel princes possess. I will only write, at present, of what befell in the conquest, and I will not write much, in order to avoid prolixity.

"Governor Pizarro wished to obtain intelligence from some Indians who had come from Cajamarca, so he had them tortured. They confessed that they had heard that Atahuallpa was waiting for the Governor at Cajamarca. The Governor then ordered us to advance. On reaching the entrance to Cajamarca, we saw the camp of Atahuallpa at a distance of a league, in the skirts of the mountains. The Indians' camp looked like a very beautiful city. They had so many tents that we were all filled with great apprehension. Until then, we had never seen anything like this in the Indies. It filled all our Spaniards with fear and confusion. But we could not show any fear or turn back, for if the Indians had sensed any weakness in us, even the Indians that we were bringing with us as guides would have killed us. So we made a show of good spirits, and after carefully observing the town and the tents, we descended into the valley and entered Caja¬marca.

"We talked a lot among ourselves about what to do. All of us were full of fear, because we were so few in number and we had penetrated so far into a land where we could not hope to receive reinforcements. We all met with the Governor to debate what we should undertake the next day. Few of us slept that night, and we kept watch in the square of Cajamarca, looking at the campfires of the Indian army. It was a frightening sight. Most of the campfires were on a hillside and so close to each other that it looked like the sky brightly studded with stars. There was no distinction that night between the mighty and the lowly, or between foot soldiers and horsemen. Everyone carried out sentry duty fully armed. So too did the good old Governor, who went about encouraging his men. The Governor's brother Hernando Pizarro estimated the number of Indian soldiers there at 40,000, but he was telling a lie just to encourage us, for there were actually more than 80,000 Indians.

"On the next morning a messenger from Atahuallpa arrived, and the Governor said to him, 'Tell your lord to come when and how he pleases, and that, in what way soever he may come I will receive him as a friend and brother. I pray that he may come quickly, for I desire to see him. No harm or insult will befall him.'

"The Governor concealed his troops around the square at Cajamarca, dividing the cavalry into two portions of which he gave the command of one to his brother Hernando Pizarro and the command of the other to Hernando de Soto. In like manner he divided the infantry, he himself tak-ing one part and giving the other to his brother Juan Pizarro. At the same time, he ordered Pedro de Candia with two or three infantrymen to go with trumpets to a small fort in the plaza and to station themselves there with a small piece of artillery. When all the Indians, and Atahuallpa with them, had entered the Plaza, the Governor would give a signal to Candia and his men, after which they should start firing the gun, and the trumpets should sound, and at the sound of the trumpets the cavalry should dash out of the large court where they were waiting hidden in readiness.

"At noon Atahuallpa began to draw up his men and to approach. Soon we saw the entire plain full of Indians, halting periodically to wait for more Indians who kept filing out of the camp behind them. They kept filling out in separate detachments into the afternoon. The front detachments were now close to our camp, and still more troops kept issuing from the camp of the Indians. In front of Atahuallpa went 2,000 Indians who swept the road ahead of him, and these were followed by the warriors, half of whom were marching in the fields on one side of him and half on the other side.

"First came a squadron of Indians dressed in clothes of different colors, like a chessboard. They advanced, removing the straws from the ground and sweeping the road. Next came three squadrons in different dresses, dancing and singing. Then came a number of men with armor, large metal plates, and crowns of gold and silver. So great was the amount of furniture of gold and silver which they bore, that it was a marvel to observe how the sun glinted upon it. Among them came the figure of Atahuallpa in a very fine litter with the ends of its timbers covered in silver. Eighty lords carried him on their shoulders, all wearing a very rich blue livery. Atahuallpa himself was very richly dressed, with his crown on his head and a collar of large emeralds around his neck. He sat on a small stool with a rich saddle cushion resting on his litter. The litter was lined with parrot feathers of many colors and decorated with plates of gold and silver.

"Behind Atahuallpa came two other litters and two hammocks, in which were some high chiefs, then several squadrons of Indians with crowns of gold and silver. These Indian squadrons began to enter the plaza to the accompaniment of great songs, and thus entering they occupied every part of the plaza. In the meantime all of us Spaniards were waiting ready, hidden in a courtyard, full of fear. Many of us urinated without noticing it, out of sheer terror. On reaching the center of the plaza, Atahuallpa remained in his litter on high, while his troops continued to file in behind him.

"Governor Pizarro now sent Friar Vicente de Valverde to go speak to Atahuallpa, and to require Atahuallpa in the name of God and of the King of Spain that Atahuallpa subject himself to the law of our Lord Jesus Christ and to the service of His Majesty the King of Spain. Advancing with a cross in one hand and the Bible in the other hand, and going among the Indian troops up to the place where Atahuallpa was, the Friar thus addressed him: 'I am a Priest of God, and I teach Christians the things of God, and in like manner I come to teach you. What I teach is that which God says to us in this Book. Therefore, on the part of God and of the Christians, I beseech you to be their friend, for such is God's will, and it will be for your good.'

"Atahuallpa asked for the Book, that he might look at it, and the Friar gave it to him closed. Atahuallpa did not know how to open the Book, and the Friar was extending his arm to do so, when Atahuallpa, in great anger, gave him a blow on the arm, not wishing that it should be opened. Then he opened it himself, and, without any astonishment at the letters and paper he threw it away from him five or six paces, his face a deep crimson.

"The Friar returned to Pizarro, shouting, 'Come out! Come out, Christians! Come at these enemy dogs who reject the things of God. That tyrant has thrown my book of holy law to the ground! Did you not see what happened? Why remain polite and servile toward this over-proud dog when the plains are full of Indians? March out against him, for I absolve you!'

"The governor then gave the signal to Candia, who began to fire off the guns. At the same time the trumpets were sounded, and the armored Spanish troops, both cavalry and infantry, sallied forth out of their hiding places straight into the mass of unarmed Indians crowding the square, giving the Spanish battle cry, 'Santiago!' We had placed rattles on the horses to terrify the Indians. The booming of the guns, the blowing of the trumpets, and the rattles on the horses threw the Indians into panicked confusion. The Spaniards fell upon them and began to cut them to pieces. The Indians were so filled with fear that they climbed on top of one another, formed mounds, and suffocated each other. Since they were unarmed, they were attacked without danger to any Christian. The cavalry rode them down, killing and wounding, and following in pursuit. The infantry made so good an assault on those that remained that in a short time most of them were put to the sword.

"The Governor himself took his sword and dagger, entered the thick of the Indians with the Spaniards who were with him, and with great bravery reached Atahuallpa's litter. He fearlessly grabbed Atahuallpa's left arm and shouted 'Santiago!,' but he could not pull Atahuallpa out of his litter because it was held up high. Although we killed the Indians who held the litter, others at once took their places and held it aloft, and in this manner we spent a long time in overcoming and killing Indians. Finally seven or eight Spaniards on horseback spurred on their horses, rushed upon the litter from one side, and with great effort they heaved it over on its side. In that way Atahuallpa was captured, and the Governor took Atahuallpa to his lodging. The Indians carrying the litter, and those escorting Atahuallpa, never abandoned him: all died around him.

"The panic-stricken Indians remaining in the square, terrified at the firing of the guns and at the horses—something they had never seen—tried to flee from the square by knocking down a stretch of wall and running out onto the plain outside. Our cavalry jumped the broken wall and charged into the plain, shouting, 'Chase those with the fancy clothes! Don't let any escape! Spear them!' All of the other Indian soldiers whom Atahuallpa had brought were a mile from Cajamarca ready for battle, but not one made a move, and during all this not one Indian raised a weapon against a Spaniard. When the squadrons of Indians who had remained in the plain outside the town saw the other Indians fleeing and shouting, most of them too panicked and fled. It was an astonishing sight, for the whole valley for 15 or 20 miles was completely filled with Indians. Night had already fallen, and our cavalry were continuing to spear Indians in the fields, when we heard a trumpet calling for us to reassemble at camp.

"If night had not come on, few out of the more than 40,000 Indian troops would have been left alive. Six or seven thousand Indians lay dead, and many more had their arms cut off and other wounds. Atahuallpa himself admitted that we had killed 7,000 of his men in that battle. The man killed in one of the litters was his minister, the lord of Chincha, of whom he was very fond. All those Indians who bore Atahuallpa's litter appeared to be high chiefs and councillors. They were all killed, as well as those Indians who were carried in the other litters and hammocks. The lord of Cajamarca was also killed, and others, but their numbers were so great that they could not be counted, for all who came in attendance on Atahuallpa were great lords. It was extraordinary to see so powerful a ruler captured in so short a time, when he had come with such a mighty army. Truly, it was not accomplished by our own forces, for there were so few of us. It was by the grace of God, which is great.

"Atahuallpa's robes had been torn off when the Spaniards pulled him out of his litter. The Governor ordered clothes to be brought to him, and when Atahuallpa was dressed, the Governor ordered Atahuallpa to sit near him and soothed his rage and agitation at finding himself so quickly fallen from his high estate. The Governor said to Atahuallpa, 'Do not take it as an insult that you have been defeated and taken prisoner, for with the Christians who come with me, though so few in number, I have conquered greater kingdoms than yours, and have defeated other more powerful lords than you, imposing upon them the dominion of the Emperor, whose vassal I am, and who is King of Spain and of the universal world. We come to conquer this land by his command, that all may come to a knowledge of God and of His Holy Catholic Faith; and by reason of our good mission, God, the Creator of heaven and earth and of all things in them, permits this, in order that you may know Him and come out from the bestial and diabolical life that you lead. It is for this reason that we, being so few in number, subjugate that vast host. When you have seen the errors in which you live, you will understand the good that we have done you by coming to your land by order of his Majesty the King of Spain. Our Lord permitted that your pride should be brought low and that no Indian should be able to offend a Christian.' "

LET US NOW trace the chain of causation in this extraordinary confrontation, beginning with the immediate events. When Pizarro and Atahuallpa met at Cajamarca, why did Pizarro capture Atahuallpa and kill so many of his followers, instead of Atahuallpa's vastly more numerous forces capturing and killing Pizarro? After all, Pizarro had only 62 soldiers mounted on horses, along with 106 foot soldiers, while Atahuallpa commanded an army of about 80,000. As for the antecedents of those events, how did Atahuallpa come to be at Cajamarca at all? How did Pizarro come to be there to capture him, instead of Atahuallpa's coming to Spain to capture King Charles I? Why did Atahuallpa walk into what seems to us, with the gift of hindsight, to have been such a transparent trap? Did the factors acting in the encounter of Atahuallpa and Pizarro also play a broader role in encounters between Old World and New World peoples and between other peoples?

Why did Pizarro capture Atahuallpa? Pizarro's military advantages lay in the Spaniards' steel swords and other weapons, steel armor, guns, and horses. To those weapons, Atahuallpa's troops, without animals on which to ride into battle, could oppose only stone, bronze, or wooden clubs, maces, and hand axes, plus slingshots and quilted armor. Such imbalances of equipment were decisive in innumerable other confrontations of Europeans with Native Americans and other peoples.

The sole Native Americans able to resist European conquest for many centuries were those tribes that reduced the military disparity by acquiring and mastering both horses and guns. To the average white American, the word "Indian" conjures up an image of a mounted Plains Indian brandishing a rifle, like the Sioux warriors who annihilated General George Custer's U.S. Army battalion at the famous battle of the Little Big Horn in 1876. We easily forget that horses and rifles were originally unknown to Native Americans. They were brought by Europeans and proceeded to transform the societies of Indian tribes that acquired them. Thanks to their mastery of horses and rifles, the Plains Indians of North America, the Araucanian Indians of southern Chile, and the Pampas Indians of Argentina fought off invading whites longer than did any other Native Americans, succumbing only to massive army operations by white governments in the 1870s and 1880s.

Today, it is hard for us to grasp the enormous numerical odds against which the Spaniards' military equipment prevailed. At the battle of Cajamarca recounted above, 168 Spaniards crushed a Native American army 500 times more numerous, killing thousands of natives while not losing a single Spaniard. Time and again, accounts of Pizarro's subsequent battles with the Incas, Cortes's conquest of the Aztecs, and other early European campaigns against Native Americans describe encounters in which a few dozen European horsemen routed thousands of Indians with great slaughter. During Pizarro's march from Cajamarca to the Inca capital of Cuzco after Atahuallpa's death, there were four such battles: at Jauja, Vilcashuaman, Vilcaconga, and Cuzco. Those four battles involved a mere 80, 30, 110, and 40 Spanish horsemen, respectively, in each case ranged against thousands or tens of thousands of Indians.

These Spanish victories cannot be written off as due merely to the help of Native American allies, to the psychological novelty of Spanish weapons and horses, or (as is often claimed) to the Incas' mistaking Spaniards for their returning god Viracocha. The initial successes of both Pizarro and Cortes did attract native allies. However, many of them would not have become allies if they had not already been persuaded, by earlier devastating successes of unassisted Spaniards, that resistance was futile and that they should side with the likely winners. The novelty of horses, steel weapons, and guns undoubtedly paralyzed the Incas at Cajamarca, but the battles after Cajamarca were fought against determined resistance by Inca armies that had already seen Spanish weapons and horses. Within half a dozen years of the initial conquest, Incas mounted two desperate, large-scale, well-prepared rebellions against the Spaniards. All those efforts failed because of the Spaniards' far superior armament.

By the 1700s, guns had replaced swords as the main weapon favoring European invaders over Native Americans and other native peoples. For example, in 1808 a British sailor named Charlie Savage equipped with muskets and excellent aim arrived in the Fiji Islands. The aptly named Savage proceeded single-handedly to upset Fiji's balance of power. Among his many exploits, he paddled his canoe up a river to the Fijian village of Kasavu, halted less than a pistol shot's length from the village fence, and fired away at the undefended inhabitants. His victims were so numerous that surviving villagers piled up the bodies to take shelter behind them, and the stream beside the village was red with blood. Such examples of the power of guns against native peoples lacking guns could be multiplied indefinitely.

In the Spanish conquest of the Incas, guns played only a minor role. The guns of those times (so-called harquebuses) were difficult to load and fire, and Pizarro had only a dozen of them. They did produce a big psychological effect on those occasions when they managed to fire. Far more important were the Spaniards' steel swords, lances, and daggers, strong sharp weapons that slaughtered thinly armored Indians. In contrast, Indian blunt clubs, while capable of battering and wounding Spaniards and their horses, rarely succeeded in killing them. The Spaniards' steel or chain mail armor and, above all, their steel helmets usually provided an effective defense against club blows, while the Indians' quilted armor offered no protection against steel weapons.

The tremendous advantage that the Spaniards gained from their horses leaps out of the eyewitness accounts. Horsemen could easily outride Indian sentries before the sentries had time to warn Indian troops behind them, and could ride down and kill Indians on foot. The shock of a horse's charge, its maneuverability, the speed of attack that it permitted, and the raised and protected fighting platform that it provided left foot soldiers nearly helpless in the open. Nor was the effect of horses due only to the terror that they inspired in soldiers fighting against them for the first time. By the time of the great Inca rebellion of 1536, the Incas had learned how best to defend themselves against cavalry, by ambushing and annihilating Spanish horsemen in narrow passes. But the Incas, like all other foot soldiers, were never able to defeat cavalry in the open. When Quizo Yupanqui, the best general of the Inca emperor Manco, who succeeded Atahuallpa, besieged the Spaniards in Lima in 1536 and tried to storm the city, two squadrons of Spanish cavalry charged a much larger Indian force on flat ground, killed Quizo and all of his commanders in the first charge, and routed his army. A similar cavalry charge of 26 horsemen routed the best troops of Emperor Manco himself, as he was besieging the Spaniards in Cuzco.

The transformation of warfare by horses began with their domestication around 4000 B.C., in the steppes north of the Black Sea. Horses permitted people possessing them to cover far greater distances than was possible on foot, to attack by surprise, and to flee before a superior defending force could be gathered. Their role at Cajamarca thus exemplifies a military weapon that remained potent for 6,000 years, until the early 20th century, and that was eventually applied on all the continents. Not until the First World War did the military dominance of cavalry finally end. When we consider the advantages that Spaniards derived from horses, steel weapons, and armor against foot soldiers without metal, it should no longer surprise us that Spaniards consistently won battles against enormous odds.

How did Atahuallpa come to be at Cajamarca? Atahuallpa and his army came to be at Cajamarca because they had just won decisive battles in a civil war that left the Incas divided and vulnerable. Pizarro quickly appreciated those divisions and exploited them. The reason for the civil war was that an epidemic of smallpox, spreading overland among South American Indians after its arrival with Spanish settlers in Panama and Colombia, had killed the Inca emperor Huayna Capac and most of his court around 1526, and then immediately killed his designated heir, Ninan Cuyuchi. Those deaths precipitated a contest for the throne between Atahuallpa and his half brother Huascar. If it had not been for the epidemic, the Spaniards would have faced a united empire.

Atahuallpa's presence at Cajamarca thus highlights one of the key factors in world history: diseases transmitted to peoples lacking immunity by invading peoples with considerable immunity. Smallpox, measles, influenza, typhus, bubonic plague, and other infectious diseases endemic in Europe played a decisive role in European conquests, by decimating many peoples on other continents. For example, a smallpox epidemic devastated the Aztecs after the failure of the first Spanish attack in 1520 and killed Cuitlahuac, the Aztec emperor who briefly succeeded Montezuma.

Throughout the Americas, diseases introduced with Europeans spread from tribe to tribe far in advance of the Europeans themselves, killing an estimated 95 percent of the pre-Columbian Native American population. The most populous and highly organized native societies of North America, the Mississippian chiefdoms, disappeared in that way between 1492 and the late 1600s, even before Europeans themselves made their first settlement on the Mississippi River. A smallpox epidemic in 1713 was the biggest single step in the destruction of South Africa's native San people by European settlers. Soon after the British settlement of Sydney in 1788, the first of the epidemics that decimated Aboriginal Australians began. A well-documented example from Pacific islands is the epidemic that swept over Fiji in 1806, brought by a few European sailors who struggled ashore from the wreck of the ship *Argo.* Similar epidemics marked the histories of Tonga, Hawaii, and other Pacific islands.

I do not mean to imply, however, that the role of disease in history was confined to paving the way for European expansion. Malaria, yellow fever, and other diseases of tropical Africa, India, Southeast Asia, and New Guinea furnished the most important obstacle to European colonization of those tropical areas.

How did Pizarro come to be at Cajamarca? Why didn't Atahuallpa instead try to conquer Spain? Pizarro came to Cajamarca by means of European maritime technology, which built the ships that took him across the Atlantic from Spain to Panama, and then in the Pacific from Panama to Peru. Lacking such technology, Atahuallpa did not expand overseas out of South America.

In addition to the ships themselves, Pizarro's presence depended on the centralized political organization that enabled Spain to finance, build, staff, and equip the ships. The Inca Empire also had a centralized political organization, but that actually worked to its disadvantage, because Pizarro seized the Inca chain of command intact by capturing Atahuallpa. Since the Inca bureaucracy was so strongly identified with its godlike absolute monarch, it disintegrated after Atahuallpa's death. Maritime technology coupled with political organization was similarly essential for European expansions to other continents, as well as for expansions of many other peoples.

A related factor bringing Spaniards to Peru was the existence of writing. Spain possessed it, while the Inca Empire did not. Information could be spread far more widely, more accurately, and in more detail by writing than it could be transmitted by mouth. That information, coming back to Spain from Columbus's voyages and from Cortes's conquest of Mexico, sent Spaniards pouring into the New World. Letters and pamphlets supplied both the motivation and the necessary detailed sailing directions. The first published report of Pizarro's exploits, by his companion Captain Cristobal de Mena, was printed in Seville in April 1534, a mere nine months after Atahuallpa's execution. It became a best-seller, was rapidly translated into other European languages, and sent a further stream of Spanish colonists to tighten Pizarro's grip on Peru.

Why did Atahuallpa walk into the trap? In hindsight, we find it astonishing that Atahuallpa marched into Pizarro's obvious trap at Cajamarca. The Spaniards who captured him were equally surprised at their success. The consequences of literacy are prominent in the ultimate explanation.

The immediate explanation is that Atahuallpa had very little information about the Spaniards, their military power, and their intent. He derived that scant information by word of mouth, mainly from an envoy who had visited Pizarro's force for two days while it was en route inland from the coast. That envoy saw the Spaniards at their most disorganized, told Atahuallpa that they were not fighting men, and that he could tie them all up if given 200 Indians. Understandably, it never occurred to Atahuallpa that the Spaniards were formidable and would attack him without provocation.

In the New World the ability to write was confined to small elites among some peoples of modern Mexico and neighboring areas far to the north of the Inca Empire. Although the Spanish conquest of Panama, a mere 600 miles from the Incas' northern boundary, began already in 1510, no knowledge even of the Spaniards' existence appears to have reached the Incas until Pizarro's first landing on the Peruvian coast in 1527. Atahuallpa remained entirely ignorant about Spain's conquests of Central America's most powerful and populous Indian societies.

As surprising to us today as Atahuallpa's behavior leading to his capture is his behavior thereafter. He offered his famous ransom in the naive belief that, once paid off, the Spaniards would release him and depart. He had no way of understanding that Pizarro's men formed the spearhead of a force bent on permanent conquest, rather than an isolated raid.

Atahuallpa was not alone in these fatal miscalculations. Even after Atahuallpa had been captured, Francisco Pizarro's brother Hernando Pizarro deceived Atahuallpa's leading general, Chalcuchima, commanding a large army, into delivering himself to the Spaniards. Chalcuchima's miscalculation marked a turning point in the collapse of Inca resistance, a moment almost as significant as the capture of Atahuallpa himself. The Aztec emperor Montezuma miscalculated even more grossly when he took Cortes for a returning god and admitted him and his tiny army into the Aztec capital of Tenochtitlan. The result was that Cortes captured Montezuma, then went on to conquer Tenochtitlan and the Aztec Empire.

On a mundane level, the miscalculations by Atahuallpa, Chalcuchima, Montezuma, and countless other Native American leaders deceived by Europeans were due to the fact that no living inhabitants of the New World had been to the Old World, so of course they could have had no specific information about the Spaniards. Even so, we find it hard to avoid the conclusion that Atahuallpa "should" have been more suspicious, if only his society had experienced a broader range of human behavior. Pizarro too arrived at Cajamarca with no information about the Incas other than what he had learned by interrogating the Inca subjects he encountered in 1527 and 1531. However, while Pizarro himself happened to be illiterate, he belonged to a literate tradition. From books, the Spaniards knew of many contemporary civilizations remote from Europe, and about several thousand years of European history. Pizarro explicitly modeled his ambush of Atahuallpa on the successful strategy of Cortes.

In short, literacy made the Spaniards heirs to a huge body of knowledge about human behavior and history. By contrast, not only did Atahuallpa have no conception of the Spaniards themselves, and no personal experience of any other invaders from overseas, but he also had not even heard (or read) of similar threats to anyone else, anywhere else, anytime previously in history. That gulf of experience encouraged Pizarro to set his trap and Atahuallpa to walk into it.

THUS, PIZARRO'S CAPTURE of Atahuallpa illustrates the set of proximate factors that resulted in Europeans' colonizing the New World instead of Native Americans' colonizing Europe. Immediate reasons for Pizarro's success included military technology based on guns, steel weapons, and horses; infectious diseases endemic in Eurasia; European maritime technology; the centralized political organization of European states; and writing. The title of this book will serve as shorthand for those proximate factors, which also enabled modern Europeans to conquer peoples of other continents. Long before anyone began manufacturing guns and steel, others of those same factors had led to the expansions of some non-European peoples, as we shall see in later chapters.

But we are still left with the fundamental question why all those immediate advantages came to lie more with Europe than with the New World. Why weren't the Incas the ones to invent guns and steel swords, to be mounted on animals as fearsome as horses, to bear diseases to which European lacked resistance, to develop oceangoing ships and advanced political organization, and to be able to draw on the experience of thousands of years of written history? Those are no longer the questions of proximate causation that this chapter has been discussing, but questions of ultimate causation that will take up the next two parts of this book.

CHAPTER 4

FARMER POWER

AS A TEENAGER, I SPENT THE SUMMER OF 1956 IN MONtana, working for an elderly farmer named Fred Hirschy. Born in Switzerland, Fred had come to southwestern Montana as a teenager in the 1890s and proceeded to develop one of the first farms in the area. At the time of his arrival, much of the original Native American population of hunter-gatherers was still living there.

My fellow farmhands were, for the most part, tough whites whose normal speech featured strings of curses, and who spent their weekdays working so that they could devote their weekends to squandering their week's wages in the local saloon. Among the farmhands, though, was a member of the Blackfoot Indian tribe named Levi, who behaved very differently from the coarse miners—being polite, gentle, responsible, sober, and well spoken. He was the first Indian with whom I had spent much time, and I came to admire him.

It was therefore a shocking disappointment to me when, one Sunday morning, Levi too staggered in drunk and cursing after a Saturday-night binge. Among his curses, one has stood out in my memory: "Damn you, Fred Hirschy, and damn the ship that brought you from Switzerland!" It poignantly brought home to me the Indians' perspective on what I, like other white schoolchildren, had been taught to view as the heroic conquest of the American West. Fred Hirschy's family was proud of him, as a pioneer farmer who had succeeded under difficult conditions. But Levi's tribe of hunters and famous warriors had been robbed of its lands by the immigrant white farmers. How did the farmers win out over the famous warriors?

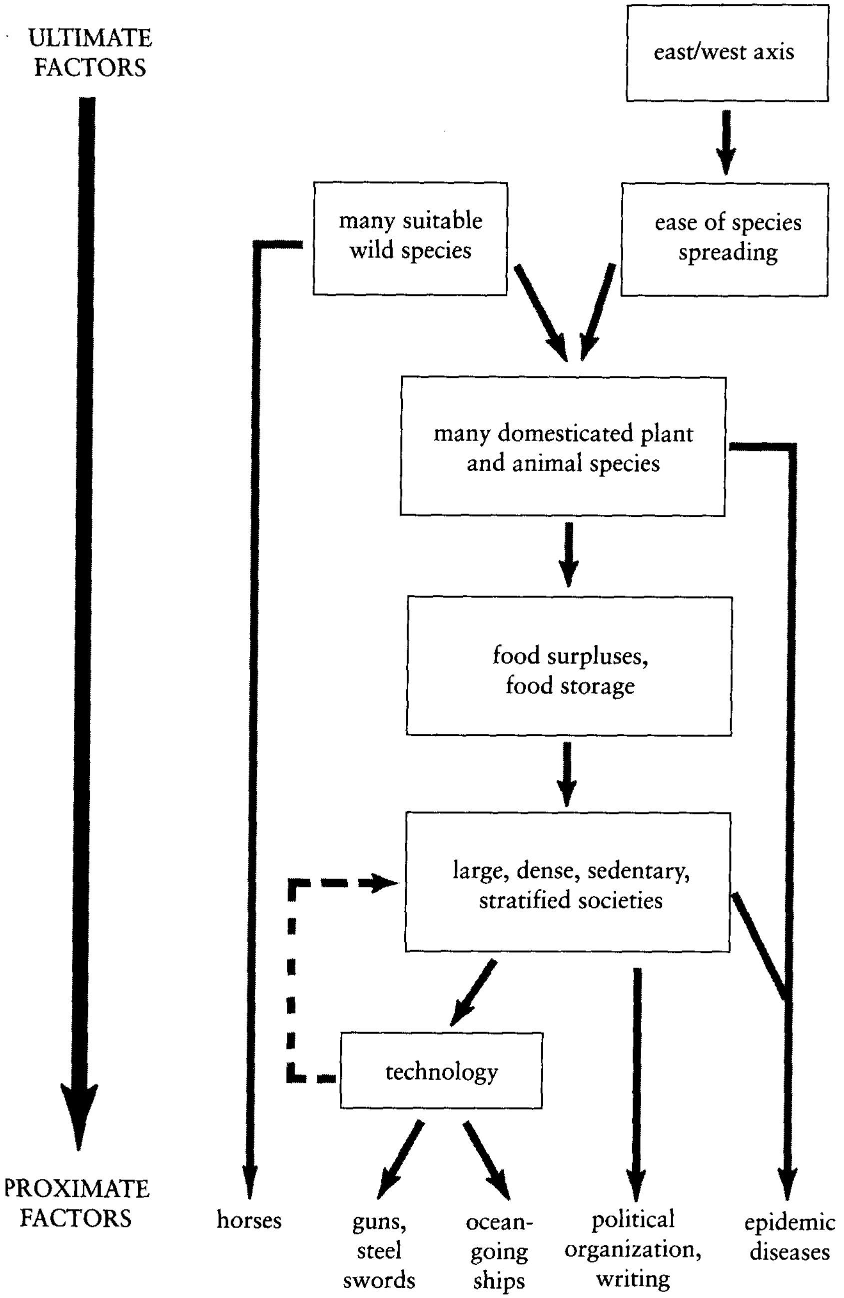
For most of the time since the ancestors of modern humans diverged from the ancestors of the living great apes, around 7 million years ago, all humans on Earth fed themselves exclusively by hunting wild animals and gathering wild plants, as the Blackfeet still did in the 19th century. It was only within the last 11,000 years that some peoples turned to what is termed food production: that is, domesticating wild animals and plants and eating the resulting livestock and crops. Today, most people on Earth consume food that they produced themselves or that someone else produced for them. At current rates of change, within the next decade the few remaining bands of hunter-gatherers will abandon their ways, disintegrate, or die out, thereby ending our millions of years of commitment to the hunter-gatherer lifestyle.

Different peoples acquired food production at different times in prehistory. Some, such as Aboriginal Australians, never acquired it at all. Of those who did, some (for example, the ancient Chinese) developed it independently by themselves, while others (including ancient Egyptians) acquired it from neighbors. But, as we'll see, food production was indirectly a prerequisite for the development of guns, germs, and steel. Hence geographic variation in whether, or when, the peoples of different continents became farmers and herders explains to a large extent their subsequent contrasting fates. Before we devote the next six chapters to understanding how geographic differences in food production arose, this chapter will trace the main connections through which food production led to all the advantages that enabled Pizarro to capture Atahuallpa, and Fred Hirschy's people to dispossess Levi's (Figure 4.1).

The first connection is the most direct one: availability of more consum-

Figure 4.1. Schematic overview of the chains of causation leading up to proximate factors (such as guns, horses, and diseases) enabling some peoples to conquer other peoples, from ultimate factors (such as the orientation of continental axes). For example, diverse epidemic diseases of humans evolved in areas with many wild plant and animal species suitable for domestication, partly because the resulting crops and livestock

Factors Underlying the Broadest Pattern of History



helped feed dense societies in which epidemics could maintain themselves, and partly because the diseases evolved from germs of the domestic animals themselves.

able calories means more people. Among wild plant and animal species, only a small minority are edible to humans or worth hunting or gathering. Most species are useless to us as food, for one or more of the following reasons: they are indigestible (like bark), poisonous (monarch butterflies and death-cap mushrooms), low in nutritional value (jellyfish), tedious to prepare (very small nuts), difficult to gather (larvae of most insects), or dangerous to hunt (rhinoceroses). Most biomass (living biological matter) on land is in the form of wood and leaves, most of which we cannot digest.

By selecting and growing those few species of plants and animals that we can eat, so that they constitute 90 percent rather than 0.1 percent of the biomass on an acre of land, we obtain far more edible calories per acre. As a result, one acre can feed many more herders and farmers—typically, 10 to 100 times more—than hunter-gatherers. That strength of brute numbers was the first of many military advantages that food-producing tribes gained over hunter-gatherer tribes.

In human societies possessing domestic animals, livestock fed more people in four distinct ways: by furnishing meat, milk, and fertilizer and by pulling plows. First and most directly, domestic animals became the societies' major source of animal protein, replacing wild game. Today, for instance, Americans tend to get most of their animal protein from cows, pigs, sheep, and chickens, with game such as venison just a rare delicacy. In addition, some big domestic mammals served as sources of milk and of milk products such as butter, cheese, and yogurt. Milked mammals include the cow, sheep, goat, horse, reindeer, water buffalo, yak, and Arabian and Bactrian camels. Those mammals thereby yield several times more calories over their lifetime than if they were just slaughtered and consumed as meat.

Big domestic mammals also interacted with domestic plants in two ways to increase crop production. First, as any modern gardener or farmer still knows by experience, crop yields can be greatly increased by manure applied as fertilizer. Even with the modern availability of synthetic fertilizers produced by chemical factories, the major source of crop fertilizer today in most societies is still animal manure—especially of cows, but also of yaks and sheep. Manure has been valuable, too, as a source of fuel for fires in traditional societies.

In addition, the largest domestic mammals interacted with domestic plants to increase food production by pulling plows and thereby making it possible for people to till land that had previously been uneconomical for farming. Those plow animals were the cow, horse, water buffalo, Bali cattle, and yak / cow hybrids. Here is one example of their value: the first prehistoric farmers of central Europe, the so-called Linearbandkeramik culture that arose slightly before 5000 B.C., were initially confined to soils light enough to be tilled by means of hand-held digging sticks. Only over a thousand years later, with the introduction of the ox-drawn plow, were those farmers able to extend cultivation to a much wider range of heavy soils and tough sods. Similarly, Native American farmers of the North American Great Plains grew crops in the river valleys, but farming of the tough sods on the extensive uplands had to await 19th-century Europeans and their animal-drawn plows.

All those are direct ways in which plant and animal domestication led to denser human populations by yielding more food than did the hunter-gatherer lifestyle. A more indirect way involved the consequences of the sedentary lifestyle enforced by food production. People of many hunter-gatherer societies move frequently in search of wild foods, but farmers must remain near their fields and orchards. The resulting fixed abode contributes to denser human populations by permitting a shortened birth interval. A hunter-gatherer mother who is shifting camp can carry only one child, along with her few possessions. She cannot afford to bear her next child until the previous toddler can walk fast enough to keep up with the tribe and not hold it back. In practice, nomadic hunter-gatherers space their children about four years apart by means of lactational amenorrhea, sexual abstinence, infanticide, and abortion. By contrast, sedentary people, unconstrained by problems of carrying young children on treks, can bear and raise as many children as they can feed. The birth interval for many farm peoples is around two years, half that of hunter-gatherers. That higher birthrate of food producers, together with their ability to feed more people per acre, lets them achieve much higher population densities than hunter-gatherers.

A separate consequence of a settled existence is that it permits one to store food surpluses, since storage would be pointless if one didn't remain nearby to guard the stored food. While some nomadic hunter-gatherers may occasionally bag more food than they can consume in a few days, such a bonanza is of little use to them because they cannot protect it. But stored food is essential for feeding non-food-producing specialists, and certainly for supporting whole towns of them. Hence nomadic hunter-gatherer societies have few or no such full-time specialists, who instead first appear in sedentary societies.

Two types of such specialists are kings and bureaucrats. Hunter-gatherer societies tend to be relatively egalitarian, to lack full-time bureaucrats and hereditary chiefs, and to have small-scale political organization at the level of the band or tribe. That's because all able-bodied hunter-gatherers are obliged to devote much of their time to acquiring food. In contrast, once food can be stockpiled, a political elite can gain control of food produced by others, assert the right of taxation, escape the need to feed itself, and engage full-time in political activities. Hence moderate-sized agricultural societies are often organized in chiefdoms, and kingdoms are confined to large agricultural societies. Those complex political units are much better able to mount a sustained war of conquest than is an egalitarian band of hunters. Some hunter-gatherers in especially rich environments, such as the Pacific Northwest coast of North America and the coast of Ecuador, also developed sedentary societies, food storage, and nascent chiefdoms, but they did not go farther on the road to kingdoms.

A stored food surplus built up by taxation can support other full-time specialists besides kings and bureaucrats. Of most direct relevance to wars of conquest, it can be used to feed professional soldiers. That was the decisive factor in the British Empire's eventual defeat of New Zealand's well-armed indigenous Maori population. While the Maori achieved some stunning temporary victories, they could not maintain an army constantly in the field and were in the end worn down by 18,000 full-time British troops. Stored food can also feed priests, who provide religious justification for wars of conquest; artisans such as metalworkers, who develop swords, guns, and other technologies; and scribes, who preserve far more information than can be remembered accurately.

So far, I've emphasized direct and indirect values of crops and livestock as food. However, they have other uses, such as keeping us warm and providing us with valuable materials. Crops and livestock yield natural fibers for making clothing, blankets, nets, and rope. Most of the major centers of plant domestication evolved not only food crops but also fiber crops—notably cotton, flax (the source of linen), and hemp. Several domestic animals yielded animal fibers—especially wool from sheep, goats, llamas, and alpacas, and silk from silkworms. Bones of domestic animals were important raw materials for artifacts of Neolithic peoples before the development of metallurgy. Cow hides were used to make leather. One of the earliest cultivated plants in many parts of the Americas was grown for nonfood purposes: the bottle gourd, used as a container.

Big domestic mammals further revolutionized human society by becoming our main means of land transport until the development of railroads in the 19th century. Before animal domestication, the sole means of transporting goods and people by land was on the backs of humans. Large mammals changed that: for the first time in human history, it became possible to move heavy goods in large quantities, as well as people, rapidly overland for long distances. The domestic animals that were ridden were the horse, donkey, yak, reindeer, and Arabian and Bactrian camels. Animals of those same five species, as well as the llama, were used to bear packs. Cows and horses were hitched to wagons, while reindeer and dogs pulled sleds in the Arctic. The horse became the chief means of long-distance transport over most of Eurasia. The three domestic camel species (Arabian camel, Bactrian camel, and llama) played a similar role in areas of North Africa and Arabia, Central Asia, and the Andes, respectively.

The most direct contribution of plant and animal domestication to wars of conquest was from Eurasia's horses, whose military role made them the jeeps and Sherman tanks of ancient warfare on that continent. As I mentioned in Chapter 3, they enabled Cortes and Pizarro, leading only small bands of adventurers, to overthrow the Aztec and Inca Empires. Even much earlier (around 4000 B.C.), at a time when horses were still ridden bareback, they may have been the essential military ingredient behind the westward expansion of speakers of Indo-European languages from the Ukraine. Those languages eventually replaced all earlier western European languages except Basque. When horses later were yoked to wagons and other vehicles, horse-drawn battle chariots (invented around 1800 B.C.) proceeded to revolutionize warfare in the Near East, the Mediterranean region, and China. For example, in 1674 B.C., horses even enabled a foreign people, the Hyksos, to conquer then horseless Egypt and to establish themselves temporarily as pharaohs.

Still later, after the invention of saddles and stirrups, horses allowed the Huns and successive waves of other peoples from the Asian steppes to terrorize the Roman Empire and its successor states, culminating in the Mongol conquests of much of Asia and Russia in the 13th and 14th centuries A.D. Only with the introduction of trucks and tanks in World War I did horses finally become supplanted as the main assault vehicle and means of fast transport in war. Arabian and Bactrian camels played a similar military role within their geographic range. In all these examples, peoples with domestic horses (or camels), or with improved means of using them, enjoyed an enormous military advantage over those without them.

Of equal importance in wars of conquest were the germs that evolved in human societies with domestic animals. Infectious diseases like smallpox, measles, and flu arose as specialized germs of humans, derived by mutations of very similar ancestral germs that had infected animals (Chapter 11). The humans who domesticated animals were the first to fall victim to the newly evolved germs, but those humans then evolved substantial resistance to the new diseases. When such partly immune people came into contact with others who had had no previous exposure to the germs, epidemics resulted in which up to *99* percent of the previously unexposed population was killed. Germs thus acquired ultimately from domestic animals played decisive roles in the European conquests of Native Americans, Australians, South Africans, and Pacific islanders.

In short, plant and animal domestication meant much more food and hence much denser human populations. The resulting food surpluses, and (in some areas) the animal-based means of transporting those surpluses, were a prerequisite for the development of settled, politically centralized, socially stratified, economically complex, technologically innovative societies. Hence the availability of domestic plants and animals ultimately explains why empires, literacy, and steel weapons developed earliest in Eurasia and later, or not at all, on other continents. The military uses of horses and camels, and the killing power of animal-derived germs, complete the list of major links between food production and conquest that we shall be exploring.

CHAPTER 8

APPLES OR INDIANS

WE HAVE JUST SEEN HOW PEOPLES OF SOME REGIONS began to cultivate wild plant species, a step with momentous unforeseen consequences for their lifestyle and their descendants' place in history. Let us now return to our questions: Why did agriculture never arise independently in some fertile and highly suitable areas, such as California, Europe, temperate Australia, and subequatorial Africa? Why, among the areas where agriculture did arise independently, did it develop much earlier in some than in others?

Two contrasting explanations suggest themselves: problems with the local people, or problems with the locally available wild plants. On the one hand, perhaps almost any well-watered temperate or tropical area of the globe offers enough species of wild plants suitable for domestication. In that case, the explanation for agriculture's failure to develop in some of those areas would lie with cultural characteristics of their peoples. On the other hand, perhaps at least some humans in any large area of the globe would have been receptive to the experimentation that led to domestication. Only the lack of suitable wild plants might then explain why food production did not evolve in some areas.

As we shall see in the next chapter, the corresponding problem for domestication of big wild mammals proves easier to solve, because there are many fewer species of them than of plants. The world holds only about 148 species of large wild mammalian terrestrial herbivores or omnivores, the large mammals that could be considered candidates for domestication. Only a modest number of factors determines whether a mammal is suitable for domestication. It's thus straightforward to review a region's big mammals and to test whether the lack of mammal domestication in some regions was due to the unavailability of suitable wild species, rather than to local peoples.

That approach would be much more difficult to apply to plants because of the sheer number—200,000—of species of wild flowering plants, the plants that dominate vegetation on the land and that have furnished almost all of our crops. We can't possibly hope to examine all the wild plant species of even a circumscribed area like California, and to assess how many of them would have been domesticable. But we shall now see how to get around that problem.

WHEN ONE HEARS that there are so many species of flowering plants, one's first reaction might be as follows: surely, with all those wild plant species on Earth, any area with a sufficiently benign climate must have had more than enough species to provide plenty of candidates for crop development.

But then reflect that the vast majority of wild plants are unsuitable for obvious reasons: they are woody, they produce no edible fruit, and their leaves and roots are also inedible. Of the 200,000 wild plant species, only a few thousand are eaten by humans, and just a few hundred of these have been more or less domesticated. Even of these several hundred crops, most provide minor supplements to our diet and would not by themselves have sufficed to support the rise of civilizations. A mere dozen species account for over 80 percent of the modern world's annual tonnage of all crops. Those dozen blockbusters are the cereals wheat, corn, rice, barley, and sorghum; the pulse soybean; the roots or tubers potato, manioc, and sweet potato; the sugar sources sugarcane and sugar beet; and the fruit banana. Cereal crops alone now account for more than half of the calories consumed by the world's human populations. With so few major crops in the world, all of them domesticated thousands of years ago, it's less surprising that many areas of the world had no wild native plants at all of outstanding potential. Our failure to domesticate even a single major new food plant in modern times suggests that ancient peoples really may have explored virtually all useful wild plants and domesticated all the ones worth domesticating.

Yet some of the world's failures to domesticate wild plants remain hard to explain. The most flagrant cases concern plants that were domesticated in one area but not in another. We can thus be sure that it was indeed possible to develop the wild plant into a useful crop, and we have to ask why that wild species was not domesticated in certain areas.

A typical puzzling example comes from Africa. The important cereal sorghum was domesticated in Africa's Sahel zone, just south of the Sahara. It also occurs as a wild plant as far south as southern Africa, yet neither it nor any other plant was cultivated in southern Africa until the arrival of the whole crop package that Bantu farmers brought from Africa north of the equator 2,000 years ago. Why did the native peoples of southern Africa not domesticate sorghum for themselves?

Equally puzzling is the failure of people to domesticate flax in its wild range in western Europe and North Africa, or einkorn wheat in its wild range in the southern Balkans. Since these two plants were among the first eight crops of the Fertile Crescent, they were presumably among the most readily domesticated of all wild plants. They were adopted for cultivation in those areas of their wild range outside the Fertile Crescent as soon as they arrived with the whole package of food production from the Fertile Crescent. Why, then, had peoples of those outlying areas not already begun to grow them of their own accord?

Similarly, the four earliest domesticated fruits of the Fertile Crescent all had wild ranges stretching far beyond the eastern Mediterranean, where they appear to have been first domesticated: the olive, grape, and fig occurred west to Italy and Spain and Northwest Africa, while the date palm extended to all of North Africa and Arabia. These four were evidently among the easiest to domesticate of all wild fruits. Why did peoples outside the Fertile Crescent fail to domesticate them, and begin to grow them only when they had already been domesticated in the eastern Mediterranean and arrived thence as crops?

Other striking examples involve wild species that were not domesticated in areas where food production never arose spontaneously, even though those wild species had close relatives domesticated elsewhere. For example, the olive *Olea europea* was domesticated in the eastern Mediterranean. There are about 40 other species of olives in tropical and southern

Africa, southern Asia, and eastern Australia, some of them closely related to *Olea europea,* but none of them was ever domesticated. Similarly, while a wild apple species and a wild grape species were domesticated in Eurasia, there are many related wild apple and grape species in North America, some of which have in modern times been hybridized with the crops derived from their wild Eurasian counterparts in order to improve those crops. Why, then, didn't Native Americans domesticate those apparently useful apples and grapes themselves?

One can go on and on with such examples. But there is a fatal flaw in this reasoning: plant domestication is not a matter of hunter-gatherers' domesticating a single plant and otherwise carrying on unchanged with their nomadic lifestyle. Suppose that North American wild apples really would have evolved into a terrific crop if only Indian hunter-gatherers had settled down and cultivated them. But nomadic hunter-gatherers would not throw over their traditional way of life, settle in villages, and start tending apple orchards unless many other domesticable wild plants and animals were available to make a sedentary food-producing existence competitive with a hunting-gathering existence.

How, in short, do we assess the potential of an entire local flora for domestication? For those Native Americans who failed to domesticate North American apples, did the problem really lie with the Indians or with the apples?

In order to answer this question, we shall now compare three regions that lie at opposite extremes among centers of independent domestication. As we have seen, one of them, the Fertile Crescent, was perhaps the earliest center of food production in the world, and the site of origin of several of the modern world's major crops and almost all of its major domesticated animals. The other two regions, New Guinea and the eastern United States, did domesticate local crops, but these crops were very few in variety, only one of them gained worldwide importance, and the resulting food package failed to support extensive development of human technology and political organization as in the Fertile Crescent. In the light of this comparison, we shall ask: Did the flora and environment of the Fertile Crescent have clear advantages over those of New Guinea and the eastern United States?

ONE OF THE central facts of human history is the early importance of the part of Southwest Asia known as the Fertile Crescent (because of the crescent-like shape of its uplands on a map: see Figure 8.1). That area appears to have been the earliest site for a whole string of developments, including cities, writing, empires, and what we term (for better or worse) civilization. All those developments sprang, in turn, from the dense human populations, stored food surpluses, and feeding of nonfarming specialists made possible by the rise of food production in the form of crop cultivation and animal husbandry. Food production was the first of those major innovations to appear in the Fertile Crescent. Hence any attempt to understand the origins of the modern world must come to grips with the question why the Fertile Crescent's domesticated plants and animals gave it such a potent head start.

Fortunately, the Fertile Crescent is by far the most intensively studied and best understood part of the globe as regards the rise of agriculture. For most crops domesticated in or near the Fertile Crescent, the wild plant ancestor has been identified; its close relationship to the crop has been proven by genetic and chromosomal studies; its wild geographic range is known; its changes under domestication have been identified and are often understood at the level of single genes; those changes can be observed in

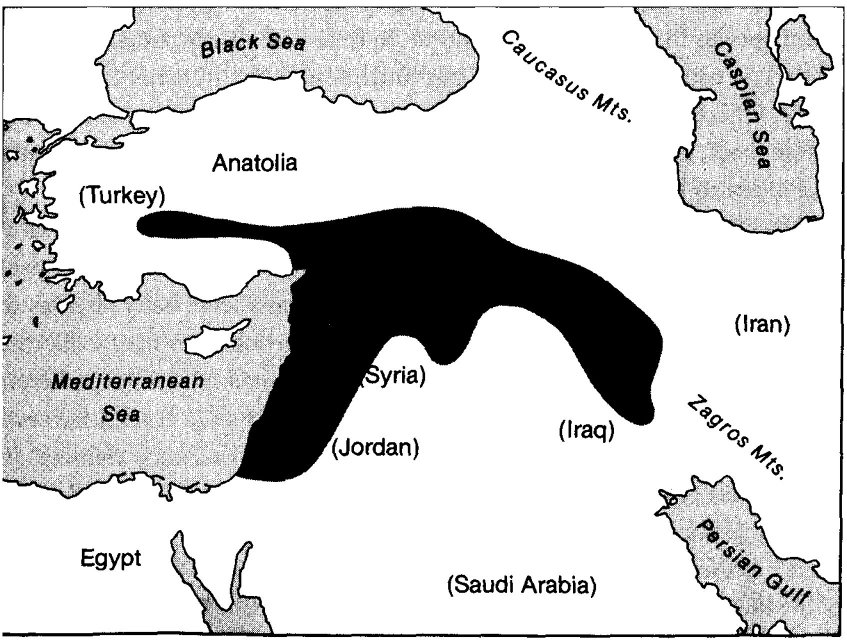


Figure 8.1. The Fertile Crescent, encompassing sites of food production before 7000 B.C.

successive layers of the archaeological record; and the approximate place and time of domestication are known. I don't deny that other areas, notably China, also had advantages as early sites of domestication, but those advantages and the resulting development of crops can be specified in much more detail for the Fertile Crescent.

One advantage of the Fertile Crescent is that it lies within a zone of so-called Mediterranean climate, a climate characterized by mild, wet winters and long, hot, dry summers. That climate selects for plant species able to survive the long dry season and to resume growth rapidly upon the return of the rains. Many Fertile Crescent plants, especially species of cereals and pulses, have adapted in a way that renders them useful to humans: they are annuals, meaning that the plant itself dries up and dies in the dry season.

Within their mere one year of life, annual plants inevitably remain small herbs. Many of them instead put much of their energy into producing big seeds, which remain dormant during the dry season and are then ready to sprout when the rains come. Annual plants therefore waste little energy on making inedible wood or fibrous stems, like the body of trees and bushes. But many of the big seeds, notably those of the annual cereals and pulses, are edible by humans. They constitute 6 of the modern world's 12 major crops. In contrast, if you live near a forest and look out your window, the plant species that you see will tend to be trees and shrubs, most of whose body you cannot eat and which put much less of their energy into edible seeds. Of course, some forest trees in areas of wet climate do produce big edible seeds, but these seeds are not adapted to surviving a long dry season and hence to long storage by humans.

A second advantage of the Fertile Crescent flora is that the wild ancestors of many Fertile Crescent crops were already abundant and highly productive, occurring in large stands whose value must have been obvious to hunter-gatherers. Experimental studies in which botanists have collected seeds from such natural stands of wild cereals, much as hunter-gatherers must have been doing over 10,000 years ago, show that annual harvests of up to nearly a ton of seeds per hectare can be obtained, yielding 50 kilocalories of food energy for only one kilocalorie of work expended. By collecting huge quantities of wild cereals in a short time when the seeds were ripe, and storing them for use as food through the rest of the year, some hunting-gathering peoples of the Fertile Crescent had already settled down in permanent villages even before they began to cultivate plants.

Since Fertile Crescent cereals were so productive in the wild, few additional changes had to be made in them under cultivation. As we discussed in the preceding chapter, the principal changes—the breakdown of the natural systems of seed dispersal and of germination inhibition—evolved automatically and quickly as soon as humans began to cultivate the seeds in fields. The wild ancestors of our wheat and barley crops look so similar to the crops themselves that the identity of the ancestor has never been in doubt. Because of this ease of domestication, big-seeded annuals were the first, or among the first, crops developed not only in the Fertile Crescent but also in China and the Sahel.

Contrast this quick evolution of wheat and barley with the story of corn, the leading cereal crop of the New World. Corn's probable ancestor, a wild plant known as teosinte, looks so different from corn in its seed and flower structures that even its role as ancestor has been hotly debated by botanists for a long time. Teosinte's value as food would not have impressed hunter-gatherers: it was less productive in the wild than wild wheat, it produced much less seed than did the corn eventually developed from it, and it enclosed its seeds in inedible hard coverings. For teosinte to become a useful crop, it had to undergo drastic changes in its reproductive biology, to increase greatly its investment in seeds, and to lose those rock-like coverings of its seeds. Archaeologists are still vigorously debating how many centuries or millennia of crop development in the Americas were required for ancient corn cobs to progress from a tiny size up to the size of a human thumb, but it seems clear that several thousand more years were then required for them to reach modern sizes. That contrast between the immediate virtues of wheat and barley and the difficulties posed by teosinte may have been a significant factor in the differing developments of New World and Eurasian human societies.

A third advantage of the Fertile Crescent flora is that it includes a high percentage of hermaphroditic "selfers"—that is, plants that usually pollinate themselves but that are occasionally cross-pollinated. Recall that most wild plants either are regularly cross-pollinated hermaphrodites or consist of separate male and female individuals that inevitably depend on another individual for pollination. Those facts of reproductive biology vexed early farmers, because, as soon as they had located a productive mutant plant, its offspring would cross-breed with other plant individuals and thereby lose their inherited advantage. As a result, most crops belong to the small percentage of wild plants that either are hermaphrodites usually pollinating themselves or else reproduce without sex by propagating vegetatively (for example, by a root that genetically duplicates the parent plant). Thus, the high percentage of hermaphroditic selfers in the Fertile Crescent flora aided early farmers, because it meant that a high percentage of the wild flora had a reproductive biology convenient for humans.

Selfers were also convenient for early farmers in that they occasionally did become cross-pollinated, thereby generating new varieties among which to select. That occasional cross-pollination occurred not only between individuals of the same species, but also between related species to produce interspecific hybrids. One such hybrid among Fertile Crescent selfers, bread wheat, became the most valuable crop in the modern world.

Of the first eight significant crops to have been domesticated in the Fertile Crescent, all were selfers. Of the three selfer cereals among them—einkorn wheat, emmer wheat, and barley—the wheats offered the additional advantage of a high protein content, 8-14 percent. In contrast, the most important cereal crops of eastern Asia and of the New World—rice and corn, respectively—had a lower protein content that posed significant nutritional problems.

THOSE WERE SOME of the advantages that the Fertile Crescent's flora afforded the first farmers: it included an unusually high percentage of wild plants suitable for domestication. However, the Mediterranean climate zone of the Fertile Crescent extends westward through much of southern Europe and northwestern Africa. There are also zones of similar Mediterranean climates in four other parts of the world: California, Chile, southwestern Australia, and South Africa (Figure 8.2). Yet those other Mediterranean zones not only failed to rival the Fertile Crescent as early sites of food production; they never gave rise to indigenous agriculture at all. What advantage did that particular Mediterranean zone of western Eurasia enjoy?

It turns out that it, and especially its Fertile Crescent portion, possessed at least five advantages over other Mediterranean zones. First, western Eurasia has by far the world's largest zone of Mediterranean climate. As a result, it has a high diversity of wild plant and animal species, higher than in the comparatively tiny Mediterranean zones of southwestern Australia and Chile. Second, among Mediterranean zones, western Eurasia's experiences the greatest climatic variation from season to season and year to year. That variation favored the evolution, among the flora, of an espe-

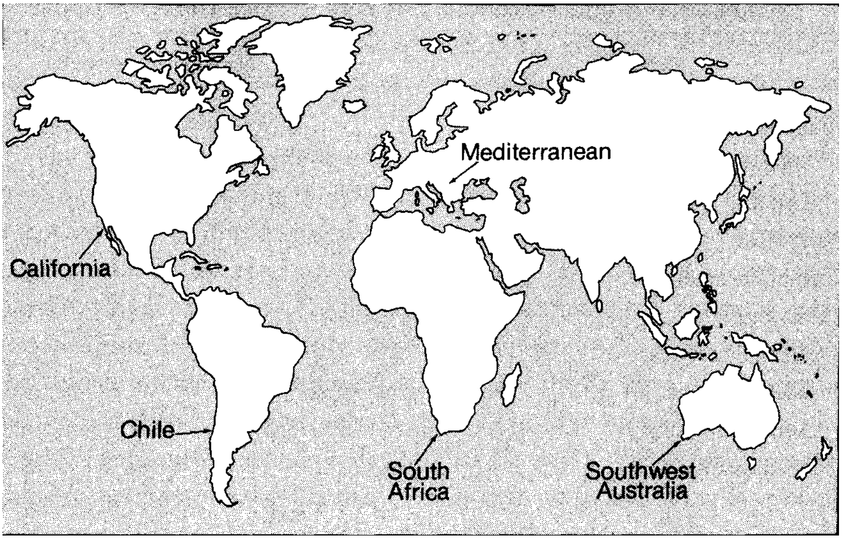


Figure 8.2. The world's zones of Mediterranean climate.

daily high percentage of annual plants. The combination of these two factors—a high diversity of species and a high percentage of annuals—means that western Eurasia's Mediterranean zone is the one with by far the highest diversity of annuals.

The significance of that botanical wealth for humans is illustrated by the geographer Mark Blunder's studies of wild grass distributions. Among the world's thousands of wild grass species, Blumler tabulated the 56 with the largest seeds, the cream of nature's crop: the grass species with seeds at least 10 times heavier than the median grass species (see Table 8.1). Virtually all of them are native to Mediterranean zones or other seasonally dry environments. Furthermore, they are overwhelmingly concentrated in the Fertile Crescent or other parts of western Eurasia's Mediterranean zone, which offered a huge selection to incipient farmers: about 32 of the world's 56 prize wild grasses! Specifically, barley and emmer wheat, the two earliest important crops of the Fertile Crescent, rank respectively 3rd and 13th in seed size among those top 56. In contrast, the Mediterranean zone of Chile offered only two of those species, California and southern Africa just one each, and southwestern Australia none at all. That fact alone goes a long way toward explaining the course of human history.

A third advantage of the Fertile Crescent's Mediterranean zone is that

TABLE 8.1 **World Distribution** of Large-Seeded Grass Species

Area		*Number of Species*
West Asia, Europe, North Africa		33
Mediterranean zone	32	
England	1	
East Asia		6
Sub-Saharan Africa		4
Americas		11
North America	4	
Mesoamerica	5	
South America	2	
Northern Australia		2
	Total:	56

Table 12.1 of Mark Blunder's Ph.D. dissertation, "Seed Weight and Environment in Mediterranean-type Grasslands in California and Israel" (University of California, Berkeley, 1992), listed the world's 56 heaviest-seeded wild grass species (excluding bamboos) for which data were available. Grain weight in those species ranged from 10 milligrams to over 40 milligrams, about 10 times greater than the median value for all of the world's grass species. Those 56 species make up less than 1 percent of the world's grass species. This table shows that these prize grasses are overwhelmingly concentrated in the Mediterranean zone of western Eurasia.

it provides a wide range of altitudes and topographies within a short distance. Its range of elevations, from the lowest spot on Earth (the Dead Sea) to mountains of 18,000 feet (near Teheran), ensures a corresponding variety of environments, hence a high diversity of the wild plants serving as potential ancestors of crops. Those mountains are in proximity to gentle lowlands with rivers, flood plains, and deserts suitable for irrigation agriculture. In contrast, the Mediterranean zones of southwestern Australia and, to a lesser degree, of South Africa and western Europe offer a narrower range of altitudes, habitats, and topographies.

The range of altitudes in the Fertile Crescent meant staggered harvest seasons: plants at higher elevations produced seeds somewhat later than plants at lower elevations. As a result, hunter-gatherers could move up a mountainside harvesting grain seeds as they matured, instead of being overwhelmed by a concentrated harvest season at a single altitude, where **all** grains matured simultaneously. When cultivation began, it was a simple matter for the first farmers to take the seeds of wild cereals growing on hillsides and dependent on unpredictable rains, and to plant those seeds in the damp valley bottoms, where they would grow reliably and be less dependent on rain.

The Fertile Crescent's biological diversity over small distances contributed to a fourth advantage—its wealth in ancestors not only of valuable crops but also of domesticated big mammals. As we shall see, there were few or no wild mammal species suitable for domestication in the other Mediterranean zones of California, Chile, southwestern Australia, and South Africa. In contrast, four species of big mammals—the goat, sheep, pig, and cow—were domesticated very early in the Fertile Crescent, possibly earlier than any other animal except the dog anywhere else in the world. Those species remain today four of the world's five most important domesticated mammals (Chapter 9). But their wild ancestors were commonest in slightly different parts of the Fertile Crescent, with the result that the four species were domesticated in different places: sheep possibly in the central part, goats either in the eastern part at higher elevations (the Zagros Mountains of Iran) or in the southwestern part (the Levant), pigs in the north-central part, and cows in the western part, including Anatolia. Nevertheless, even though the areas of abundance of these four wild progenitors thus differed, all four lived in sufficiently close proximity that they were readily transferred after domestication from one part of the Fertile Crescent to another, and the whole region ended up with all four species.

Agriculture was launched in the Fertile Crescent by the early domestication of eight crops, termed "founder crops" (because they founded agriculture in the region and possibly in the world). Those eight founders were the cereals emmer wheat, einkorn wheat, and barley; the pulses lentil, pea, chickpea, and bitter vetch; and the fiber crop flax. Of these eight, only two, flax and barley, range in the wild at all widely outside the Fertile Crescent and Anatolia. Two of the founders had very small ranges in the wild, chickpea being confined to southeastern Turkey and emmer wheat to the Fertile Crescent itself. Thus, agriculture could arise in the Fertile Crescent from domestication of locally available wild plants, without having to wait for the arrival of crops derived from wild plants domesticated elsewhere. Conversely, two of the eight founder crops could not have been domesticated anywhere in the world except in the Fertile Crescent, since they did not occur wild elsewhere.

Thanks to this availability of suitable wild mammals and plants, early peoples of the Fertile Crescent could quickly assemble a potent and balanced biological package for intensive food production. That package comprised three cereals, as the main carbohydrate sources; four pulses, with 20-25 percent protein, and four domestic animals, as the main protein sources, supplemented by the generous protein content of wheat; and flax as a source of fiber and oil (termed linseed oil: flax seeds are about 40 percent oil). Eventually, thousands of years after the beginnings of animal domestication and food production, the animals also began to be used for milk, wool, plowing, and transport. Thus, the crops and animals of the Fertile Crescent's first farmers came to meet humanity's basic economic needs: carbohydrate, protein, fat, clothing, traction, and transport.

A final advantage of early food production in the Fertile Crescent is that it may have faced less competition from the hunter-gatherer lifestyle than that in some other areas, including the western Mediterranean. Southwest Asia has few large rivers and only a short coastline, providing relatively meager aquatic resources (in the form of river and coastal fish and shellfish). One of the important mammal species hunted for meat, the gazelle, originally lived in huge herds but was overexploited by the growing human population and reduced to low numbers. Thus, the food production package quickly became superior to the hunter-gatherer package. Sedentary villages based on cereals were already in existence before the rise of food production and predisposed those hunter-gatherers to agriculture and herding. In the Fertile Crescent the transition from hunting-gathering to food production took place relatively fast: as late as 9000 B.C. people still had no crops and domestic animals and were entirely dependent on wild foods, but by 6000 B.C. some societies were almost completely dependent on crops and domestic animals.

The situation in Mesoamerica contrasts strongly: that area provided only two domesticable animals (the turkey and the dog), whose meat yield was far lower than that of cows, sheep, goats, and pigs; and corn, Meso¬america's staple grain, was, as I've already explained, difficult to domesticate and perhaps slow to develop. As a result, domestication may not have begun in Mesoamerica until around 3500 B.c. (the date remains very uncertain); those first developments were undertaken by people who were still nomadic hunter-gatherers; and settled villages did not arise there until around 1500 B.C.

IN ALL THIS discussion of the Fertile Crescent's advantages for the early rise of food production, we have not had to invoke any supposed advantages of Fertile Crescent peoples themselves. Indeed, I am unaware of anyone's even seriously suggesting any supposed distinctive biological features of the region's peoples that might have contributed to the potency of its food production package. Instead, we have seen that the many distinctive features of the Fertile Crescent's climate, environment, wild plants, and animals together provide a convincing explanation.

Since the food production packages arising indigenously in New Guinea and in the eastern United States were considerably less potent, might the explanation there lie with the peoples of those areas? Before turning to those regions, however, we must consider two related questions arising in regard to any area of the world where food production never developed independently or else resulted in a less potent package. First, do hunter-gatherers and incipient farmers really know well all locally available wild species and their uses, or might they have overlooked potential ancestors of valuable crops? Second, if they do know their local plants and animals, do they exploit that knowledge to domesticate the most useful available species, or do cultural factors keep them from doing so?

As regards the first question, an entire field of science, termed ethnobiology, studies peoples' knowledge of the wild plants and animals in their environment. Such studies have concentrated especially on the world's few surviving hunting-gathering peoples, and on farming peoples who still depend heavily on wild foods and natural products. The studies generally show that such peoples are walking encyclopedias of natural history, with individual names (in their local language) for as many as a thousand or more plant and animal species, and with detailed knowledge of those species' biological characteristics, distribution, and potential uses. As people become increasingly dependent on domesticated plants and animals, this traditional knowledge gradually loses its value and becomes lost, until one arrives at modern supermarket shoppers who could not distinguish a wild grass from a wild pulse.

Here's a typical example. For the last 33 years, while conducting biological exploration in New Guinea, I have been spending my field time there constantly in the company of New Guineans who still use wild plants and animals extensively. One day, when my companions of the Fore tribe and I were starving in the jungle because another tribe was blocking our return to our supply base, a Fore man returned to camp with a large rucksack full of mushrooms he had found, and started to roast them. Dinner at last! But then I had an unsettling thought: what if the mushrooms were poisonous?

I patiently explained to my Fore companions that I had read about some mushrooms' being poisonous, that I had heard of even expert American mushroom collectors' dying because of the difficulty of distinguishing safe from dangerous mushrooms, and that although we were all hungry, it just wasn't worth the risk. At that point my companions got angry and told me to shut up and listen while they explained some things to me. After I had been quizzing them for years about names of hundreds of trees and birds, how could I insult them by assuming they didn't have names for different mushrooms? Only Americans could be so stupid as to confuse poisonous mushrooms with safe ones. They went on to lecture me about 29 types of edible mushroom species, each species' name in the Fore language, and where in the forest one should look for it. This one, the *tanti,* grew on trees, and it was delicious and perfectly edible.

Whenever I have taken New Guineans with me to other parts of their island, they regularly talk about local plants and animals with other New Guineans whom they meet, and they gather potentially useful plants and bring them back to their home villages to try planting them. My experiences with New Guineans are paralleled by those of ethnobiologists studying traditional peoples elsewhere. However, all such peoples either practice at least some food production or are the partly acculturated last remnants of the world's former hunter-gatherer societies. Knowledge of wild species was presumably even more detailed before the rise of food production, when everyone on Earth still depended entirely on wild species for food. The first farmers were heirs to that knowledge, accumulated through tens of thousands of years of nature observation by biologically modern humans living in intimate dependence on the natural world. It therefore seems extremely unlikely that wild species of potential value would have escaped the notice of the first farmers.

The other, related question is whether ancient hunter-gatherers and farmers similarly put their ethnobiological knowledge to good use in selecting wild plants to gather and eventually to cultivate. One test comes from an archaeological site at the edge of the Euphrates Valley in Syria, called Tell Abu Hureyra. Between 10,000 and 9000 B.C. the people living there may already have been residing year-round in villages, but they were still hunter-gatherers; crop cultivation began only in the succeeding millennium. The archaeologists Gordon Hillman, Susan Colledge, and David Harris retrieved large quantities of charred plant remains from the site, probably representing discarded garbage of wild plants gathered elsewhere and brought to the site by its residents. The scientists analyzed over 700 samples, each containing an average of over 500 identifiable seeds belonging to over 70 plant species. It turned out that the villagers were collecting a prodigious variety (157 species!) of plants identified by their charred seeds, not to mention other plants that cannot now be identified.

Were those naive villagers collecting every type of seed plant that they found, bringing it home, poisoning themselves on most of the species, and nourishing themselves from only a few species? No, they were not so silly. While 157 species sounds like indiscriminate collecting, many more species growing wild in the vicinity were absent from the charred remains. The 157 selected species fall into three categories. Many of them have seeds that are nonpoisonous and immediately edible. Others, such as pulses and members of the mustard family, have toxic seeds, but the toxins are easily removed, leaving the seeds edible. A few seeds belong to species traditionally used as sources of dyes or medicine. The many wild species not represented among the 157 selected are ones that would have been useless or harmful to people, including all of the most toxic weed species in the environment.

Thus, the hunter-gatherers of Tell Abu Hureyra were not wasting time and endangering themselves by collecting wild plants indiscriminately. Instead, they evidently knew the local wild plants as intimately as do modern New Guineans, and they used that knowledge to select and bring home only the most useful available seed plants. But those gathered seeds would have constituted the material for the unconscious first steps of plant domestication.

My other example of how ancient peoples apparently used their ethnobiological knowledge to good effect comes from the Jordan Valley in the ninth millennium B.C., the period of the earliest crop cultivation there. The valley's first domesticated cereals were barley and emmer wheat, which are still among the world's most productive crops today. But, as at Tell Abu Hureyra, hundreds of other seed-bearing wild plant species must have grown in the vicinity, and a hundred or more of them would have been edible and gathered before the rise of plant domestication. What was it about barley and emmer wheat that caused them to be the first crops? Were those first Jordan Valley farmers botanical ignoramuses who didn't know what they were doing? Or were barley and emmer wheat actually the best of the local wild cereals that they could have selected?

Two Israeli scientists, Ofer Bar-Yosef and Mordechai Kislev, tackled this question by examining the wild grass species still growing wild in the valley today. Leaving aside species with small or unpalatable seeds, they picked out 23 of the most palatable and largest-seeded wild grasses. Not surprisingly, barley and emmer wheat were on that list.

But it wasn't true that the 21 other candidates would have been equally useful. Among those 23, barley and emmer wheat proved to be the best by many criteria. Emmer wheat has the biggest seeds and barley the second biggest. In the wild, barley is one of the 4 most abundant of the 23 species, while emmer wheat is of medium abundance. Barley has the further advantage that its genetics and morphology permit it to evolve quickly the useful changes in seed dispersal and germination inhibition that we discussed in the preceding chapter. Emmer wheat, however, has compensating virtues: it can be gathered more efficiently than barley, and it is unusual among cereals in that its seeds do not adhere to husks. As for the other 21 species, their drawbacks include smaller seeds, in many cases lower abundance, and in some cases their being perennial rather than annual plants, with the consequence that they would have evolved only slowly under domestication.

Thus, the first farmers in the Jordan Valley selected the 2 very best of the 23 best wild grass species available to them. Of course, the evolutionary changes (following cultivation) in seed dispersal and germination inhibition would have been unforeseen consequences of what those first farmers were doing. But their initial selection of barley and emmer wheat rather than other cereals to collect, bring home, and cultivate would have been conscious and based on the easily detected criteria of seed size, palatability, and abundance.

This example from the Jordan Valley, like that from Tell Abu Hureyra, illustrates that the first farmers used their detailed knowledge of local species to their own benefit. Knowing far more about local plants than all but a handful of modern professional botanists, they would hardly have failed to cultivate any useful wild plant species that was comparably suitable for domestication.

WE CAN NOW examine what local farmers, in two parts of the world (New Guinea and the eastern United States) with indigenous but apparently deficient food production systems compared to that of the Fertile Crescent, actually did when more-productive crops arrived from elsewhere. If it turned out that such crops did not become adopted for cultural or other reasons, we would be left with a nagging doubt. Despite all our reasoning so far, we would still have to suspect that the local wild flora harbored some ancestor of a potential valuable crop that local farmers failed to exploit because of similar cultural factors. These two examples will also demonstrate in detail a fact critical to history: that indigenous crops from different parts of the globe were not equally productive.

New Guinea, the largest island in the world after Greenland, lies just north of Australia and near the equator. Because of its tropical location and great diversity in topography and habitats, New Guinea is rich in both plant and animal species, though less so than continental tropical areas because it is an island. People have been living in New Guinea for at least 40,000 years—much longer than in the Americas, and slightly longer than anatomically modern peoples have been living in western Europe. Thus, New Guineans have had ample opportunity to get to know their local flora and fauna. Were they motivated to apply this knowledge to developing food production?

I mentioned already that the adoption of food production involved a *competition* between the food producing and the hunting-gathering lifestyles. Hunting-gathering is not so rewarding in New Guinea as to remove the motivation to develop food production. In particular, modern New Guinea hunters suffer from the crippling disadvantage of a dearth of wild game: there is no native land animal larger than a 100-pound flightless bird (the cassowary) and a 50-pound kangaroo. Lowland New Guineans on the coast do obtain much fish and shellfish, and some lowlanders in the interior still live today as hunter-gatherers, subsisting especially on wild sago palms. But no peoples still live as hunter-gatherers in the New Guinea highlands; all modern highlanders are instead farmers who use wild foods only to supplement their diets. When highlanders go into the forest on hunting trips, they take along garden-grown vegetables to feed themselves. If they have the misfortune to run out of those provisions, even they starve to death despite their detailed knowledge of locally available wild foods. Since the hunting-gathering lifestyle is thus nonviable in much of modern New Guinea, it comes as no surprise that all New Guinea highlanders and most lowlanders today are settled farmers with sophisticated systems of food production. Extensive, formerly forested areas of the highlands were converted by traditional New Guinea farmers to fenced, drained, intensively managed field systems supporting dense human populations.

Archaeological evidence shows that the origins of New Guinea agriculture are ancient, dating to around 7000 B.C. At those early dates all the landmasses surrounding New Guinea were still occupied exclusively by hunter-gatherers, so this ancient agriculture must have developed independently in New Guinea. While unequivocal remains of crops have not been recovered from those early fields, they are likely to have included some of the same crops that were being grown in New Guinea at the time of European colonization and that are now known to have been domesticated locally from wild New Guinea ancestors. Foremost among these local domesticates is the modern world's leading crop, sugarcane, of which the annual tonnage produced today nearly equals that of the number two and number three crops combined (wheat and corn). Other crops of undoubted New Guinea origin are a group of bananas known as *Australimusa* bananas, the nut tree *Canarium indicum,* and giant swamp taro, as well as various edible grass stems, roots, and green vegetables. The breadfruit tree and the root crops yams and (ordinary) taro may also be New Guinean domesticates, although that conclusion remains uncertain because their wild ancestors are not confined to New Guinea but are distributed from New Guinea to Southeast Asia. At present we lack evidence that could resolve the question whether they were domesticated in Southeast Asia, as traditionally assumed, or independently or even only in New Guinea.

However, it turns out that New Guinea's biota suffered from three severe limitations. First, no cereal crops were domesticated in New Guinea, whereas several vitally important ones were domesticated in the Fertile Crescent, Sahel, and China. In its emphasis instead on root and tree crops, New Guinea carries to an extreme a trend seen in agricultural systems in other wet tropical areas (the Amazon, tropical West Africa, and Southeast Asia), whose farmers also emphasized root crops but did manage to come up with at least two cereals (Asian rice and a giant-seeded Asian cereal called Job's tears). A likely reason for the failure of cereal agriculture to arise in New Guinea is a glaring deficiency of the wild starting material: not one of the world's 56 largest-seeded wild grasses is native there.

Second, the New Guinea fauna included no domesticable large mammal species whatsoever. The sole domestic animals of modern New Guinea, the pig and chicken and dog, arrived from Southeast Asia by way of Indonesia within the last several thousand years. As a result, while New Guinea lowlanders obtain protein from the fish they catch, New Guinea highland farmer populations suffer from severe protein limitation, because the staple crops that provide most of their calories (taro and sweet potato) are low in protein. Taro, for example, consists of barely 1 percent protein, much worse than even white rice, and far below the levels of the Fertile Crescent's wheats and pulses (8-14 percent and 20-25 percent protein, respectively).

Children in the New Guinea highlands have the swollen bellies characteristic of a high-bulk but protein-deficient diet. New Guineans old and young routinely eat mice, spiders, frogs, and other small animals that peoples elsewhere with access to large domestic mammals or large wild game species do not bother to eat. Protein starvation is probably also the ultimate reason why cannibalism was widespread in traditional New Guinea highland societies.

Finally, in former times New Guinea's available root crops were limiting for calories as well as for protein, because they do not grow well at the high elevations where many New Guineans live today. Many centuries ago, however, a new root crop of ultimately South American origin, the sweet potato, reached New Guinea, probably by way of the Philippines, where it had been introduced by Spaniards. Compared with taro and other presumably older New Guinea root crops, the sweet potato can be grown up to higher elevations, grows more quickly, and gives higher yields per acre cultivated and per hour of labor. The result of the sweet potato's arrival was a highland population explosion. That is, even though people had been farming in the New Guinea highlands for many thousands of years before sweet potatoes were introduced, the available local crops had limited them in the population densities they could attain, and in the elevations they could occupy.

In short, New Guinea offers an instructive contrast to the Fertile Crescent. Like hunter-gatherers of the Fertile Crescent, those of New Guinea did evolve food production independently. However, their indigenous food production was restricted by the local absence of domesticable cereals, pulses, and animals, by the resulting protein deficiency in the highlands, and by limitations of the locally available root crops at high elevations. Yet New Guineans themselves know as much about the wild plants and animals available to them as any peoples on Earth today. They can be expected to have discovered and tested any wild plant species worth domesticating. They are perfectly capable of recognizing useful additions to their crop larder, as is shown by their exuberant adoption of the sweet potato when it arrived. That same lesson is being driven home again in New Guinea today, as those tribes with preferential access to introduced new crops and livestock (or with the cultural willingness to adopt them) expand at the expense of tribes without that access or willingness. Thus, the limits on indigenous food production in New Guinea had nothing to do with New Guinea peoples, and everything with the New Guinea biota and environment.

OUR OTHER EXAMPLE **of indigenous agriculture apparently constrained** by the local flora comes from the eastern United States. Like New Guinea, that area supported independent domestication of local wild plants. However, early developments are much better understood for the eastern United States than for New Guinea: the crops grown by the earliest farmers have been identified, and the dates and crop sequences of local domestication are known. Well before other crops began to arrive from elsewhere, Native Americans settled in eastern U.S. river valleys and developed intensified food production based on local crops. Hence they were in a position to take advantage of the most promising wild plants. Which ones did they actually cultivate, and how did the resulting local crop package compare with the Fertile Crescent's founder package?

It turns out that the eastern U.S. founder crops were four plants domesticated in the period 2500-1500 B.C., a full 6,000 years after wheat and barley domestication in the Fertile Crescent. A local species of squash provided small containers, as well as yielding edible seeds. The remaining three founders were grown solely for their edible seeds (sunflower, a daisy relative called sumpweed, and a distant relative of spinach called goosefoot).

But four seed crops and a container fall far short of a complete food production package. For 2,000 years those founder crops served only as minor dietary supplements while eastern U.S. Native Americans continued to depend mainly on wild foods, especially wild mammals and waterbirds, fish, shellfish, and nuts. Farming did not supply a major part of their diet until the period 500-200 B.c., after three more seed crops (knotweed, maygrass, and little barley) had been brought into cultivation.

A modern nutritionist would have applauded those seven eastern U.S.

crops. All of them were high in protein—17-32 percent, compared with 8-14 percent for wheat, 9 percent for corn, and even lower for barley and white rice. Two of them, sunflower and sumpweed, were also high in oil (45-47 percent). Sumpweed, in particular, would have been a nutritionist's ultimate dream, being 32 percent protein and 45 percent oil. Why aren't we still eating those dream foods today?

Alas, despite their nutritional advantage, most of these eastern U.S. crops suffered from serious disadvantages in other respects. Goosefoot, knotweed, little barley, and maygrass had tiny seeds, with volumes only one-tenth that of wheat and barley seeds. Worse yet, sumpweed is a wind-pollinated relative of ragweed, the notorious hayfever-causing plant. Like ragweed's, sumpweed's pollen can cause hayfever where the plant occurs in abundant stands. If that doesn't kill your enthusiasm for becoming a sumpweed farmer, be aware that it has a strong odor objectionable to some people and that handling it can cause skin irritation.

Mexican crops finally began to reach the eastern United States by trade routes after A.D. 1. Corn arrived around A.D. 200, but its role remained very minor for many centuries. Finally, around A.D. 900 a new variety of corn adapted to North America's short summers appeared, and the arrival of beans around A.D. 1100 completed Mexico's crop trinity of corn, beans, and squash. Eastern U.S. farming became greatly intensified, and densely populated chiefdoms developed along the Mississippi River and its tributaries. In some areas the original local domesticates were retained alongside the far more productive Mexican trinity, but in other areas the trinity replaced them completely. No European ever saw sumpweed growing in Indian gardens, because it had disappeared as a crop by the time that European colonization of the Americas began, in A.D. 1492. Among all those ancient eastern U.S. crop specialties, only two (sunflower and eastern squash) have been able to compete with crops domesticated elsewhere and are still grown today. Our modern acorn squashes and summer squashes are derived from those American squashes domesticated thousands of years ago.

Thus, like the case of New Guinea, that of the eastern United States is instructive. A priori, the region might have seemed a likely one to support productive indigenous agriculture. It has rich soils, reliable moderate rainfall, and a suitable climate that sustains bountiful agriculture today. The flora is a species-rich one that includes productive wild nut trees (oak and hickory). Local Native Americans did develop an agriculture based on local domesticates, did thereby support themselves in villages, and even developed a cultural florescence (the Hopewell culture centered on what is today Ohio) around 200 B.C.-A.D. 400. They were thus in a position for several thousand years to exploit as potential crops the most useful available wild plants, whatever those should be.

Nevertheless, the Hopewell florescence sprang up nearly 9,000 years after the rise of village living in the Fertile Crescent. Still, it was not until after A.D. 900 that the assembly of the Mexican crop trinity triggered a larger population boom, the so-called Mississippian florescence, which produced the largest towns and most complex societies achieved by Native Americans north of Mexico. But that boom came much too late to prepare Native Americans of the United States for the impending disaster of European colonization. Food production based on eastern U.S. crops alone had been insufficient to trigger the boom, for reasons that are easy to specify. The area's available wild cereals were not nearly as useful as wheat and barley. Native Americans of the eastern United States domesticated no locally available wild pulse, no fiber crop, no fruit or nut tree. They had no domesticated animals at all except for dogs, which were probably domesticated elsewhere in the Americas.

It's also clear that Native Americans of the eastern United States were not overlooking potential major crops among the wild species around them. Even 20th-century plant breeders, armed with all the power of modern science, have had little success in exploiting North American wild plants. Yes, we have now domesticated pecans as a nut tree and blueberries as a fruit, and we have improved some Eurasian fruit crops (apples, plums, grapes, raspberries, blackberries, strawberries) by hybridizing them with North American wild relatives. However, those few successes have changed our food habits far less than Mexican corn changed food habits of Native Americans in the eastern United States after A.D. 900.

The farmers most knowledgeable about eastern U.S. domesticates, the region's Native Americans themselves, passed judgment on them by discarding or deemphasizing them when the Mexican trinity arrived. That outcome also demonstrates that Native Americans were not constrained by cultural conservativism and were quite able to appreciate a good plant when they saw it. Thus, as in New Guinea, the limitations on indigenous food production in the eastern United States were not due to Native American peoples themselves, but instead depended entirely on the American biota and environment.

WE HAVE NOW considered examples of three contrasting areas, in all of which food production did arise indigenously. The Fertile Crescent lies at one extreme; New Guinea and the eastern United States lie at the opposite extreme. Peoples of the Fertile Crescent domesticated local plants much earlier. They domesticated far more species, domesticated far more productive or valuable species, domesticated a much wider range of types of crops, developed intensified food production and dense human populations more rapidly, and as a result entered the modern world with more advanced technology, more complex political organization, and more epidemic diseases with which to infect other peoples.

We found that these differences between the Fertile Crescent, New Guinea, and the eastern United States followed straightforwardly from the differing suites of wild plant and animal species available for domestication, not from limitations of the peoples themselves. When more-productive crops arrived from elsewhere (the sweet potato in New Guinea, the Mexican trinity in the eastern United States), local peoples promptly took advantage of them, intensified food production, and increased greatly in population. By extension, I suggest that areas of the globe where food production never developed indigenously at all—California, Australia, the Argentine pampas, western Europe, and so on—may have offered even less in the way of wild plants and animals suitable for domestication than did New Guinea and the eastern United States, where at least a limited food production did arise. Indeed, Mark Blumler's worldwide survey of locally available large-seeded wild grasses mentioned in this chapter, and the worldwide survey of locally available big mammals to be presented in the next chapter, agree in showing that all those areas of nonexistent or limited indigenous food production were deficient in wild ancestors of domesticable livestock and cereals.

Recall that the rise of food production involved a competition between food production and hunting-gathering. One might therefore wonder whether all these cases of slow or nonexistent rise of food production might instead have been due to an exceptional local richness of resources to be hunted and gathered, rather than to an exceptional availability of species suitable for domestication. In fact, most areas where indigenous food production arose late or not at all offered exceptionally poor rather than rich resources to hunter-gatherers, because most large mammals of Australia and the Americas (but not of Eurasia and Africa) had become extinct toward the end of the Ice Ages. Food production would have faced even less competition from hunting-gathering in these areas than it did in the Fertile Crescent. Hence these local failures or limitations of food production cannot be attributed to competition from bountiful hunting opportunities.

LEST THESE CONCLUSIONS be misinterpreted, we should end this chapter with caveats against exaggerating two points: peoples' readiness to accept better crops and livestock, and the constraints imposed by locally available wild plants and animals. Neither that readiness nor those constraints are absolute.

The grimmest examples of germs' role in history come from the European conquest of the Americas that began with Columbus's voyage of 1492. Numerous as were the Native American victims of the murderous Spanish conquistadores, they were far outnumbered by the victims of murderous Spanish microbes. Why was the exchange of nasty germs between the Americas and Europe so unequal? Why didn't Native American diseases instead decimate the Spanish invaders, spread back to Europe, and wipe out *95* percent of Europe's population? Similar questions arise for the decimation of many other native peoples by Eurasian germs, as well as for the decimation of would-be European conquistadores in the tropics of Africa and Asia.

Thus, questions of the animal origins of human disease lie behind the broadest pattern of human history, and behind some of the most important issues *in* human health today. (Think of AIDS, an explosively spreading human disease that appears to have evolved from a virus resident in wild African monkeys.) This chapter will begin by considering what a "disease" is, and why some microbes have evolved so as to "make us sick," whereas most other species of living things don't make us sick. We'll examine why many of our most familiar infectious diseases run in epidemics, such as our current AIDS epidemic and the Black Death (bubonic plague) epidemics of the Middle Ages. We'll then consider how the ancestors of microbes now confined to us transferred themselves from their original animal hosts. Finally, we'll see how insight into the animal origins of our infectious diseases helps explain the momentous, almost one-way exchange of germs between Europeans and Native Americans.

NATURALLY, WE'RE DISPOSED to think about diseases just from our own point of view: what can we do to save ourselves and to kill the microbes? Let's stamp out the scoundrels, and never mind what *their* motives are! In life in general, though, one has to understand the enemy in order to beat him, and that's especially true in medicine.

Hence let's begin by temporarily setting aside our human bias and considering disease from the microbes' point of view. After all, microbes are as much a product of natural selection as we are. What evolutionary benefit does a microbe derive from making us sick in bizarre ways, like giving us genital sores or diarrhea? And why should microbes evolve so as to kill us? That seems especially puzzling and self-defeating, since a microbe that kills its host kills itself.

Basically, microbes evolve like other species. Evolution selects for those individuals most effective at producing babies and at helping them spread to suitable places to live. For a microbe, spread may be defined mathematically as the number of new victims infected per each original patient. That number depends on how long each victim remains capable of infecting new victims, and how efficiently the microbe is transferred from one victim to the next.

Microbes have evolved diverse ways of spreading from one person to another, and from animals to people. The germ that spreads better leaves more babies and ends up favored by natural selection. Many of our "symptoms" of disease actually represent ways in which some damned clever microbe modifies our bodies or our behavior such that we become enlisted to spread microbes.

The most effortless way a germ could spread is by just waiting to be transmitted passively to the next victim. That's the strategy practiced by microbes that wait for one host to be eaten by the next host: for instance, salmonella bacteria, which we contract by eating already infected eggs or meat; the worm responsible for trichinosis, which gets from pigs to us by waiting for us to kill the pig and eat it without proper cooking; and the worm causing anisakiasis, with which sushi-loving Japanese and Americans occasionally infect themselves by consuming raw fish. Those parasites pass to a person from an eaten animal, but the virus causing laughing sickness (kuru) in the New Guinea highlands used to pass to a person from another person who was eaten. It was transmitted by cannibalism, when highland babies made the fatal mistake of licking their fingers after playing with raw brains that their mothers had just cut out of dead kuru victims awaiting cooking.

Some microbes don't wait for the old host to die and get eaten, but instead hitchhike in the saliva of an insect that bites the old host and flies off to find a new host. The free ride may be provided by mosquitoes, fleas, lice, or tsetse flies that spread malaria, plague, typhus, or sleeping sickness, respectively. The dirtiest of all tricks for passive carriage is perpetrated by microbes that pass from a woman to her fetus and thereby infect babies already at birth. By playing that trick, the microbes responsible for syphilis, rubella, and now AIDS pose ethical dilemmas with which believers in a fundamentally just universe have had to struggle desperately.

Other germs take matters into their own hands, figuratively speaking. They modify the anatomy or habits of their host in such a way as to accelerate their transmission. From our perspective, the open genital sores caused by venereal diseases like syphilis are a vile indignity. From the microbes' point of view, however, they're just a useful device to enlist a host's help in inoculating microbes into a body cavity of a new host. The skin lesions caused by smallpox similarly spread microbes by direct or indirect body contact (occasionally very indirect, as when U.S. whites bent on wiping out "belligerent" Native Americans sent them gifts of blankets previously used by smallpox patients).

More vigorous yet is the strategy practiced by the influenza, common cold, and pertussis (whooping cough) microbes, which induce the victim to cough or sneeze, thereby launching a cloud of microbes toward prospective new hosts. Similarly, the cholera bacterium induces in its victim a massive diarrhea that delivers bacteria into the water supplies of potential new victims, while the virus responsible for Korean hemorrhagic fever broadcasts itself in the urine of mice. For modification of a host's behavior, nothing matches rabies virus, which not only gets into the saliva of an infected dog but drives the dog into a frenzy of biting and thus infecting many new victims. But for physical effort on the bug's own part, the prize still goes to worms such as hookworms and schistosomes, which actively burrow through a host's skin from the water or soil into which their larvae had been excreted in a previous victim's feces.

Thus, from our point of view, genital sores, diarrhea, and coughing are "symptoms of disease." From a germ's point of view, they're clever evolutionary strategies to broadcast the germ. That's why it's in the germ's interests to "make us sick." But why should a germ evolve the apparently self-defeating strategy of killing its host?

From the germ's perspective, that's just an unintended by-product (fat consolation to us!) of host symptoms promoting efficient transmission of microbes. Yes, an untreated cholera patient may eventually die from producing diarrheal fluid at a rate of several gallons per day. At least for a while, though, as long as the patient is still alive, the cholera bacterium profits from being massively broadcast into the water supplies of its next victims. Provided that each victim thereby infects on the average more than one new victim, the bacterium will spread, even though the first host happens to die.

SO MUCH FOR our dispassionate examination of the germ's interests. Now let's get back to considering our own selfish interests: to stay alive and healthy, best done by killing the damned germs. One common response of ours to infection is to develop a fever. Again, we're used to considering fever as a "symptom of disease," as if it developed inevitably without serving any function. But regulation of body temperature is under our genetic control and doesn't just happen by accident. A few microbes are more sensitive to heat than our own bodies are. By raising our body temperature, we in effect try to bake the germs to death before we get baked ourselves.

Another common response of ours is to mobilize our immune system. White blood cells and other cells of ours actively seek out and kill foreign microbes. The specific antibodies that we gradually build up against a particular microbe infecting us make us less likely to get reinfected once we become cured. As we all know from experience, there are some illnesses, such as flu and the common cold, to which our resistance is only temporary; we can eventually contract the illness again. Against other illnesses, though—including measles, mumps, rubella, pertussis, and the now defeated smallpox—our antibodies stimulated by one infection confer lifelong immunity. That's the principle of vaccination: to stimulate our antibody production without our having to go through the actual experience of the disease, by inoculating us with a dead or weakened strain of microbe.

Alas, some clever microbes don't just cave in to our immune defenses. Some have learned to trick us by changing those molecular pieces of the microbe (its so-called antigens) that our antibodies recognize. The constant evolution or recycling of new strains of flu, with differing antigens, explains why your having gotten flu two years ago didn't protect you against the different strain that arrived this year. Malaria and sleeping sickness are even more slippery customers in their ability rapidly to change their antigens. Among the slipperiest of all is AIDS, which evolves new antigens even as it sits within an individual patient, thereby eventually overwhelming his or her immune system.

Our slowest defensive response is through natural selection, which changes our gene frequencies from generation to generation. For almost any disease, some people prove to be genetically more resistant than are others. In an epidemic those people with genes for resistance to that particular microbe are more likely to survive than are people lacking such genes. As a result, over the course of history, human populations repeatedly exposed to a particular pathogen have come to consist of a higher proportion of individuals with those genes for resistance—just because unfortunate individuals without the genes were less likely to survive to pass their genes on to babies.

Fat consolation, you may be thinking again. This evolutionary response is not one that does the genetically susceptible dying individual any good. It does mean, though, that a human population as a whole becomes better protected against the pathogen. Examples of those genetic defenses include the protections (at a price) that the sickle-cell gene, Tay-Sachs gene, and cystic fibrosis gene may confer on African blacks, Ashkenazi Jews, and northern Europeans against malaria, tuberculosis, and bacterial diarrheas, respectively.

In short, our interaction with most species, as exemplified by hummingbirds, doesn't make us or the hummingbird "sick." Neither we nor hummingbirds have had to evolve defenses against each other. That peaceful relationship was able to persist because hummingbirds don't count on us to spread their babies or to offer our bodies for food. Hummingbirds evolved instead to feed on nectar and insects, which they find by using their own wings.

But microbes evolved to feed on the nutrients within our own bodies, and they don't have wings to let them reach a new victim's body once the original victim is dead or resistant. Hence many germs have had *to* evolve tricks to let them spread between potential victims, and many of those tricks are what we experience as "symptoms of disease." We've evolved countertricks of our own, to which the germs have responded by evolving counter-countertricks. We and our pathogens are now locked in an escalating evolutionary contest, with the death of one contestant the price of defeat, and with natural selection playing the role of umpire. Now let's consider the form of the contest: blitzkrieg or guerrilla war?

SUPPOSE THAT ONE counts the number of cases of some particular infectious disease in some geographic area, and watches how the numbers change with time. The resulting patterns differ greatly among diseases. For certain diseases, like malaria or hookworm, new cases appear any month of any year in an affected area. So-called epidemic diseases, though, produce no cases for a long time, then a whole wave of cases, then no more cases again for a while.

Among such epidemic diseases, influenza is one personally familiar to most Americans, certain years being particularly bad years for us (but great years for the influenza virus). Cholera epidemics come at longer intervals, the 1991 Peruvian epidemic being the first one to reach the New World during the 20th century. Although today's influenza and cholera epidemics make front-page stories, epidemics used to be far more terrifying before the rise of modern medicine. The greatest single epidemic in human history was the one of influenza that killed 21 million people at the end of the First World War. The Black Death (bubonic plague) killed one-quarter of Europe's population between 1346 and 1352, with death tolls ranging up to 70 percent in some cities. When the Canadian Pacific Railroad was being built through Saskatchewan in the early 1880s, that province's Native Americans, who had previously had little exposure to whites and their germs, died of tuberculosis at the incredible rate of 9 percent per year.

The infectious diseases that visit us as epidemics, rather than as a steady trickle of cases, share several characteristics. First, they spread quickly and efficiently from an infected person to nearby healthy people, with the result that the whole population gets exposed within a short time. Second, they're "acute" illnesses: within a short time, you either die or recover completely. Third, the fortunate ones of us who do recover develop antibodies that leave us immune against a recurrence of the disease for a long time, possibly for the rest of our life. Finally, these diseases tend to be restricted to humans; the microbes causing them tend not to live in the soil or in other animals. All four of these traits apply to what Americans think of as the familiar acute epidemic diseases of childhood, including measles, rubella, mumps, pertussis, and smallpox.

The reason why the combination of those four traits tends to make a disease run in epidemics is easy to understand. In simplified form, here's what happens. The rapid spread of microbes, and the rapid course of symptoms, mean that everybody in a local human population is quickly infected and soon thereafter is either dead or else recovered and immune. No one is left alive who could still be infected. But since the microbe can't survive except in the bodies of living people, the disease dies out, until a new crop of babies reaches the susceptible age—and until an infectious person arrives from the outside to start a new epidemic.

A classic illustration of how such diseases occur as epidemics is the history of measles on the isolated Atlantic islands called the Faeroes. A severe epidemic of measles reached the Faeroes in 1781 and then died out, leaving the islands measles free until an infected carpenter arrived on a ship from Denmark in 1846. Within three months, almost the whole Faeroes population (7,782 people) had gotten measles and then either died or recovered, leaving the measles virus to disappear once again until the next epidemic. Studies show that measles is likely to die out in any human population numbering fewer than half a million people. Only in larger populations can the disease shift from one local area to another, thereby persisting until enough babies have been born in the originally infected area that measles can return there.

What's true for measles in the Faeroes is true of our other familiar acute infectious diseases throughout the world. To sustain themselves, they need a human population that is sufficiently numerous, and sufficiently densely packed, that a numerous new crop of susceptible children is available for infection by the time the disease would otherwise be waning. Hence measles and similar diseases are also known as crowd diseases.

OBVIOUSLY, CROWD DISEASES could not sustain themselves in small bands of hunter-gatherers and slash-and-burn farmers. As tragic modern experience with Amazonian Indians and Pacific Islanders confirms, almost an entire tribelet may be wiped out by an epidemic brought by an outside visitor—because no one in the tribelet had any antibodies against the microbe. For example, in the winter of 1902 a dysentery epidemic brought by a sailor on the whaling ship *Active* killed 51 out of the 56 Sadlermiut Eskimos, a very isolated band of people living on Southampton Island in the Canadian Arctic. In addition, measles and some of our other "childhood" diseases are more likely to kill infected adults than children, and all adults in the tribelet are susceptible. (In contrast, modern Americans rarely contract measles as adults, because most of them get either measles or the vaccine against it as children.) Having killed most of the tribelet, the epidemic then disappears. The small population size of tribelets explains not only why they can't sustain epidemics introduced from the outside, but also why they never could evolve epidemic diseases of their own to give back to visitors.

That's not to say, though, that small human populations are free from all infectious diseases. They do have infections, but only of certain types. Some are caused by microbes capable of maintaining themselves in animals or in the soil, with the result that the disease doesn't die out but remains constantly available to infect people. For example, the yellow fever virus is carried by African wild monkeys, whence it can always infect rural human populations of Africa, whence it was carried by the transatlantic slave trade to infect New World monkeys and people.

Still other infections of small human populations are chronic diseases such as leprosy and yaws. Since the disease may take a very long time to kill its victim, the victim remains alive as a reservoir of microbes to infect other members of the tribelet. For instance, the Karimui Basim of the New Guinea highlands, where I worked in the 1960s, was occupied by an isolated population of a few thousand people, suffering from the world's highest incidence of leprosy—about 40 percent! Finally, small human populations are also susceptible to nonfatal infections against which we don't develop immunity, with the result that the same person can become reinfected after recovering. That happens with hookworm and many other parasites.

All these types of diseases, characteristic of small isolated populations, must be the oldest diseases of humanity. They were the ones we could evolve and sustain through the early millions of years of our evolutionary history, when the total human population was tiny and fragmented. These diseases are also shared with, or similar to the diseases of, our closest wild relatives, the African great apes. In contrast, the crowd diseases, which we discussed earlier, could have arisen only with the buildup of large, dense human populations. That buildup began with the rise of agriculture starting about 10,000 years ago and then accelerated with the rise of cities starting several thousand years ago. In fact, the first attested dates for many familiar infectious diseases are surprisingly recent: around 1600 B.c. for smallpox (as deduced from pockmarks on an Egyptian mummy), 400 B.C. for mumps, 200 B.C. for leprosy, A.D. 1840 for epidemic polio, and 1959 for AIDS.

WHY DID THE rise of agriculture launch the evolution of our crowd infectious diseases? One reason just mentioned is that agriculture sustains much higher human population densities than does the hunting-gathering lifestyle—on the average, 10 to 100 times higher. In addition, hunter-gatherers frequently shift camp and leave behind their own piles of feces with accumulated microbes and worm larvae. But farmers are sedentary and live amid their own sewage, thus providing microbes with a short path from one person's body into another's drinking water.

Some farming populations make it even easier for their own fecal bacteria and worms to infect new victims, by gathering their feces and urine and spreading them as fertilizer on the fields where people work. Irrigation agriculture and fish farming provide ideal living conditions for the snails carrying schistosomiasis and for flukes that burrow through our skin as we wade through the feces-laden water. Sedentary farmers become surrounded not only by their feces but also by disease transmitting rodents, attracted by the farmers' stored food. The forest clearings made by African farmers also provide ideal breeding habitats for malaria-transmitting mosquitoes.

If the rise of farming was thus a bonanza for our microbes, the rise of cities was a greater one, as still more densely packed human populations festered under even worse sanitation conditions. Not until the beginning of the 20th century did Europe's urban populations finally become self-sustaining: before then, constant immigration of healthy peasants from the countryside was necessary to make up for the constant deaths of city dwellers from crowd diseases. Another bonanza was the development of world trade routes, which by Roman times effectively joined the populations of Europe, Asia, and North Africa into one giant breeding ground for microbes. That's when smallpox finally reached Rome, as the Plague of Antoninus, which killed millions of Roman citizens between A.D. 165 and 180.

Similarly, bubonic plague first appeared in Europe as the Plague of Justinian (A.D. 542-43). But plague didn't begin to hit Europe with full force as the Black Death epidemics until A.D. 1346, when a new route for overland trade with China provided rapid transit, along Eurasia's east-west axis, for flea-infested furs from plague-ridden areas of Central Asia to Europe. Today, our jet planes have made even the longest intercontinental flights briefer than the duration of any human infectious disease. That's how an Aerolineas Argentinas airplane, stopping in Lima (Peru) in 1991, managed to deliver dozens of cholera-infected people that same day to my city of Los Angeles, over 3,000 miles from Lima. The explosive increase in world travel by Americans, and in immigration to the United States, is turning us into another melting pot—this time, of microbes that we previously dismissed as just causing exotic diseases in far-off countries.

THUS, WHEN THE human population became sufficiently large and concentrated, we reached the stage in our history at which we could at last evolve and sustain crowd diseases confined to our own species. But that conclusion presents a paradox: such diseases could never have existed before then! Instead, they had to evolve as new diseases. Where did those new diseases come from?

Evidence has recently been emerging from molecular studies of the disease-causing microbes themselves. For many of the microbes responsible for our unique diseases, molecular biologists can now identify the microbe's closest relatives. These also prove to be agents of crowd infectious diseases—but ones confined to various species of our domestic animals and pets! Among animals, too, epidemic diseases require large, dense populations and don't afflict just any animal: they're confined mainly to social animals providing the necessary large populations. Hence when we domesticated social animals, such as cows and pigs, they were already afflicted by epidemic diseases just waiting to be transferred to us.

For example, measles virus is most closely related to the virus causing rinderpest. That nasty epidemic disease affects cattle and many wild cud-chewing mammals, but not humans. Measles in turn doesn't afflict cattle. The close similarity of the measles virus to the rinderpest virus suggests that the latter transferred from cattle to humans and then evolved into the measles virus by changing its properties to adapt to us. That transfer is not at all surprising, considering that many peasant farmers live and sleep close to cows and their feces, urine, breath, sores, and blood. Our intimacy with cattle has been going on for the 9,000 years since we domesticated them—ample time for the rinderpest virus to discover us nearby. As Table 11.1 illustrates, others of our familiar infectious diseases can similarly be traced back to diseases of our animal friends.

GIVEN OUR PROXIMITY to the animals we love, we must be getting constantly bombarded by their microbes. Those invaders get winnowed by natural selection, and only a few of them succeed in establishing themselves as human diseases. A quick survey of current diseases lets us trace out four stages in the evolution of a specialized human disease from an animal precursor.

The first stage is illustrated by dozens of diseases that we now and then pick up directly from our pets and domestic animals. They include cat-scratch fever from our cats, leptospirosis from our dogs, psittacosis from our chickens and parrots, and brucellosis from our cattle. We're similarly liable to pick up diseases from wild animals, such as the tularemia that hunters can get from skinning wild rabbits. All those microbes are still at an early stage in their evolution into specialized human pathogens. They still don't get transmitted directly from one person to another, and even their transfer to us from animals remains uncommon.

In the second stage a former animal pathogen evolves to the point where it does get transmitted directly between people and causes epidemics.

TABLE 11.1 Deadly Gifts from Our Animal Friends

Human Disease	*Animal with Most Closely Related Pathogen*
Measles	cattle (rinderpest)
Tuberculosis	cattle
Smallpox	cattle (cowpox) or other livestock with related pox viruses
Flu	pigs and ducks
Pertussis	pigs, dogs
Falciparum malaria	birds (chickens and ducks?)

However, the epidemic dies out for any of several reasons, such as being cured by modern medicine, or being stopped when everybody around has already been infected and either becomes immune or dies. For example, a previously unknown fever termed O'nyong-nyong fever appeared in East Africa in 1959 and proceeded to infect several million Africans. It probably arose from a virus of monkeys and was transmitted to humans by mosquitoes. The fact that patients recovered quickly and became immune to further attack helped the new disease die out quickly. Closer to home for Americans, Fort Bragg fever was the name applied to a new leptospiral disease that broke out in the United States in the summer of 1942 and soon disappeared.

A fatal disease vanishing for another reason was New Guinea's laughing sickness, transmitted by cannibalism and caused by a slow-acting virus from which no one has ever recovered. Kuru was on its way to exterminating New Guinea's Fore tribe of 20,000 people, until the establishment of Australian government control around 1959 ended cannibalism and thereby the transmission of kuru. The annals of medicine are full of accounts of diseases that sound like no disease known today, but that once caused terrifying epidemics and then disappeared as mysteriously as they had come. The "English sweating sickness," which swept and terrified Europe between 1485 and 1552, and the "Picardy sweats" of 18th- and 19th-century France, are just two of the many epidemic illnesses that vanished long before modern medicine had devised methods for identifying the responsible microbes.

A third stage in the evolution of our major diseases is represented by former animal pathogens that did establish themselves in humans, that have not (not yet?) died out, and that may or may not still become major killers of humanity. The future remains very uncertain for Lassa fever, caused by a virus derived probably from rodents. Lassa fever was first observed in 1969 in Nigeria, where it causes a fatal illness so contagious that Nigerian hospitals have been closed down if even a single case appears. Better established is Lyme disease, caused by a spirochete that we get from the bite of ticks carried by mice and deer. Although the first known human cases in the United States appeared only as recently as 1962, Lyme disease is already reaching epidemic proportions in many parts of our country. The future of AIDS, derived from monkey viruses and first documented in humans around 1959, is even more secure (from the virus's perspective).

The final stage of this evolution is represented by the major, long-established epidemic diseases confined to humans. These diseases must have been the evolutionary survivors of far more pathogens that tried to make the jump to us from animals—and mostly failed.

What is actually going on in those stages, as an exclusive disease of animals transforms itself into an exclusive disease of humans? One transformation involves a change of intermediate vector: when a microbe relying on some arthropod vector for transmission switches to a new host, the microbe may be forced to find a new arthropod as well. For example, typhus was initially transmitted between rats by rat fleas, which sufficed for a while to transfer typhus from rats to humans. Eventually, typhus microbes discovered that human body lice offered a much more efficient method of traveling directly between humans. Now that Americans have mostly deloused themselves, typhus has discovered a new route into us: by infecting eastern North American flying squirrels and then transferring to people whose attics harbor flying squirrels.

In short, diseases represent evolution in progress, and microbes adapt by natural selection to new hosts and vectors. But compared with cows' bodies, ours offer different immune defenses, lice, feces, and chemistries. In that new environment, a microbe must evolve new ways to live and to propagate itself. In several instructive cases doctors or veterinarians have actually been able to observe microbes evolving those new ways.

The best-studied case involves what happened when myxomatosis hit Australian rabbits. The myxo virus, native to a wild species of Brazilian rabbit, had been observed to cause a lethal epidemic in European domestic rabbits, which are a different species. Hence the virus was intentionally introduced to Australia in 1950 in the hopes of ridding the continent of its plague of European rabbits, foolishly introduced in the nineteenth century. In the first year, myxo produced a gratifying (to Australian farmers) 99.8 percent mortality rate in infected rabbits. Unfortunately for the farmers, the death rate then dropped in the second year to 90 percent and eventually to 25 percent, frustrating hopes of eradicating rabbits completely from Australia. The problem was that the myxo virus evolved to serve its own interests, which differed from ours as well as from those of the rabbits. The virus changed so as to kill fewer rabbits and to permit lethally infected ones to live longer before dying. As a result, a less lethal myxo virus spreads baby viruses to more rabbits than did the original, highly virulent myxo.

For a similar example in humans, we have only to consider the surprising evolution of syphilis. Today, our two immediate associations to syphilis are genital sores and a very slowly developing disease, leading to the death of many untreated victims only after many years. However, when syphilis was first definitely recorded in Europe in 1495, its pustules often covered the body from the head to the knees, caused flesh to fall off people's faces, and led to death within a few months. By 1546, syphilis had evolved into the disease with the symptoms so well known to us today. Apparently, just as with myxomatosis, those syphilis spirochetes that evolved so as to keep their victims alive for longer were thereby able to transmit their spirochete offspring into more victims.

THE IMPORTANCE OF lethal microbes in human history is well illustrated by Europeans' conquest and depopulation of the New World. Far more Native Americans died in bed from Eurasian germs than on the battlefield from European guns and swords. Those germs undermined Indian resistance by killing most Indians and their leaders and by sapping the survivors' morale. For instance, in 1519 Cortes landed on the coast of Mexico with 600 Spaniards, to conquer the fiercely militaristic Aztec Empire with a population of many millions. That Cortes reached the Aztec capital of Tenochtitlan, escaped with the loss of "only" two-thirds of his force, and managed to fight his way back to the coast demonstrates both Spanish military advantages and the initial naivete of the Aztecs. But when Cortes's next onslaught came, the Aztecs were no longer naive and fought street by street with the utmost tenacity. What gave the Spaniards a decisive advantage was smallpox, which reached Mexico in 1520 with one infected slave arriving from Spanish Cuba. The resulting epidemic proceeded to kill nearly half of the Aztecs, including Emperor Cuitlahuac. Aztec survivors were demoralized by the mysterious illness that killed Indians and spared Spaniards, as if advertising the Spaniards' invincibility. By 1618, Mexico's initial population of about 20 million had plummeted to about 1.6 million.

Pizarro had similarly grim luck when he landed on the coast of Peru in 1531 with 168 men to conquer the Inca Empire of millions. Fortunately for Pizarro and unfortunately for the Incas, smallpox had arrived overland around 1526, killing much of the Inca population, including both the emperor Huayna Capac and his designated successor. As we saw in Chapter 3, the result of the throne's being left vacant was that two other sons of Huayna Capac, Atahuallpa and Huascar, became embroiled in a civil war that Pizarro exploited to conquer the divided Incas.

When we in the United States think of the most populous New World societies existing in 1492, only those of the Aztecs and the Incas tend to come to our minds. We forget that North America also supported populous Indian societies in the most logical place, the Mississippi Valley, which contains some of our best farmland today. In that case, however, conquistadores contributed nothing directly to the societies' destruction; Eurasian germs, spreading in advance, did everything. When Hernando de Soto became the first European conquistador to march through the southeastern United States, in 1540, he came across Indian town sites abandoned two years earlier because the inhabitants had died in epidemics. These epidemics had been transmitted from coastal Indians infected by Spaniards visiting the coast. The Spaniards' microbes spread to the interior in advance of the Spaniards themselves.

De Soto was still able to see some of the densely populated Indian towns lining the lower Mississippi. After the end of his expedition, it was a long time before Europeans again reached the Mississippi Valley, but Eurasian microbes were now established in North America and kept spreading. By the time of the next appearance of Europeans on the lower Mississippi, that of French settlers in the late 1600s, almost all of those big Indian towns had vanished. Their relics are the great mound sites of the Mississippi Valley. Only recently have we come to realize that many of the mound-building societies were still largely intact when Columbus reached the New World, and that they collapsed (probably as a result of disease) between 1492 and the systematic European exploration of the Mississippi.

When I was young, American schoolchildren were taught that North America had originally been occupied by only about one million Indians. That low number was useful in justifying the white conquest of what could be viewed as an almost empty continent. However, archaeological excavations, and scrutiny of descriptions left by the very first European explorers on our coasts, now suggest an initial number of around 20 million Indians. For the New World as a whole, the Indian population decline in the century or two following Columbus's arrival is estimated to have been as large as 95 percent.

The main killers were Old World germs to which Indians had never been exposed, and against which they therefore had neither immune nor genetic resistance. Smallpox, measles, influenza, and typhus competed for top rank among the killers. As if these had not been enough, diphtheria, malaria, mumps, pertussis, plague, tuberculosis, and yellow fever came up close behind. In countless cases, whites were actually there to witness the destruction occurring when the germs arrived. For example, in 1837 the Mandan Indian tribe, with one of the most elaborate cultures in our Great Plains, contracted smallpox from a steamboat traveling up the Missouri River from St. Louis. The population of one Mandan village plummeted from 2,000 to fewer than 40 within a few weeks.

WHILE OVER A dozen major infectious diseases of Old World origins became established in the New World, perhaps not a single major killer reached Europe from the Americas. The sole possible exception is syphilis, whose area of origin remains controversial. The one-sidedness of that exchange of germs becomes even more striking when we recall that large, dense human populations are a prerequisite for the evolution of our crowd infectious diseases. If recent reappraisals of the pre-Columbian New World population are correct, it was not far below the contemporary population of Eurasia. Some New World cities like Tenochtitlan were among the world's most populous cities at the time. Why didn't Tenochtitlan have awful germs waiting for the Spaniards?

One possible contributing factor is that the rise of dense human populations began somewhat later in the New World than in the Old World. Another is that the three most densely populated American centers—the Andes, Mesoamerica, and the Mississippi Valley—never became connected by regular fast trade into one huge breeding ground for microbes, in the way that Europe, North Africa, India, and China became linked in Roman times. Those factors still don't explain, though, why the New World apparently ended up with no lethal crowd epidemics at all. (Tuberculosis DNA has been reported from the mummy of a Peruvian Indian who died 1,000 years ago, but the identification procedure used did not distinguish human tuberculosis from a closely related pathogen *(Mycobacterium bovis)* that is widespread in wild animals.)

Instead, what must be the main reason for the failure of lethal crowd epidemics to arise in the Americas becomes clear when we pause to ask a simple question. From what microbes could they conceivably have evolved? We've seen that Eurasian crowd diseases evolved out of diseases of Eurasian herd animals that became domesticated. Whereas many such animals existed in Eurasia, only five animals of any sort became domesticated in the Americas: the turkey in Mexico and the U.S. Southwest, the llama / alpaca and the guinea pig in the Andes, the Muscovy duck in tropical South America, and the dog throughout the Americas.

In turn, we also saw that this extreme paucity of domestic animals in the New World reflects the paucity of wild starting material. About 80 percent of the big wild mammals of the Americas became extinct at the end of the last Ice Age, around 13,000 years ago. The few domesticates that remained to Native Americans were not likely sources of crowd diseases, compared with cows and pigs. Muscovy ducks and turkeys don't live in enormous flocks, and they're not cuddly species (like young lambs) with which we have much physical contact. Guinea pigs may have contributed a trypanosome infection like Chagas' disease or leishmaniasis to our catalog of woes, but that's uncertain. Initially, most surprising is the absence of any human disease derived from llamas (or alpacas), which it's tempting to consider the Andean equivalent of Eurasian livestock. However, llamas had four strikes against them as a source of human pathogens: they were kept in smaller herds than were sheep and goats and pigs; their total numbers were never remotely as large as those of the Eurasian populations of domestic livestock, since llamas never spread beyond the Andes; people don't drink (and get infected by) llama milk; and llamas aren't kept indoors, in close association with people. In contrast, human mothers in the New Guinea highlands often nurse piglets, and pigs as well as cows are frequently kept inside the huts of peasant farmers.

THE HISTORICAL IMPORTANCE of animal-derived diseases extends far beyond the collision of the Old and the New Worlds. Eurasian germs played a key role in decimating native peoples in many other parts of the world, including Pacific islanders, Aboriginal Australians, and the Khoisan peoples (Hottentots and Bushmen) of southern Africa. Cumulative mortalities of these previously unexposed peoples from Eurasian germs ranged from 50 percent to 100 percent. For instance, the Indian population of Hispaniola declined from around 8 million, when Columbus arrived in A.D. 1492, to zero by 1535. Measles reached Fiji with a Fijian chief returning from a visit to Australia in 1875, and proceeded to kill about one-quarter of all Fijians then alive (after most Fijians had already been killed by epidemics beginning with the first European visit, in 1791). Syphilis, gonorrhea, tuberculosis, and influenza arriving with Captain Cook in 1779, followed by a big typhoid epidemic in 1804 and numerous "minor" epidemics, reduced Hawaii's population from around half a million in 1779 to 84,000 in 1853, the year when smallpox finally reached Hawaii and killed around 10,000 of the survivors. These examples could be multiplied almost indefinitely.

However, germs did not act solely to Europeans' advantage. While the New World and Australia did not harbor native epidemic diseases awaiting Europeans, tropical Asia, Africa, Indonesia, and New Guinea certainly did. Malaria throughout the tropical Old World, cholera in tropical Southeast Asia, and yellow fever in tropical Africa were (and still are) the most notorious of the tropical killers. They posed the most serious obstacle to European colonization of the tropics, and they explain why the European colonial partitioning of New Guinea and most of Africa was not accomplished until nearly 400 years after European partitioning of the New World began. Furthermore, once malaria and yellow fever did become transmitted to the Americas by European ship traffic, they emerged as the major impediment to colonization of the New World tropics as well. A familiar example is the role of those two diseases in aborting the French effort, and nearly aborting the ultimately successful American effort, to construct the Panama Canal.

Bearing all these facts in mind, let's try to regain our sense of perspective about the role of germs in answering Yali's question. There is no doubt that Europeans developed a big advantage in weaponry, technology, and political organization over most of the non-European peoples that they conquered. But that advantage alone doesn't fully explain how initially so few European immigrants came to supplant so much of the native population of the Americas and some other parts of the world. That might not have happened without Europe's sinister gift to other continents—the germs evolving from Eurasians' long intimacy with domestic animals.

BY NOW, IT should be obvious that chiefdoms introduced the dilemma fundamental to all centrally governed, nonegalitarian societies. At best, they do good by providing expensive services impossible to contract for on an individual basis. At worst, they function unabashedly as kleptocracies, transferring net wealth from commoners to upper classes. These noble and selfish functions are inextricably linked, although some governments emphasize much more of one function than of the other. The difference between a kleptocrat and a wise statesman, between a robber baron and a public benefactor, is merely one of degree: a matter of just how large a percentage of the tribute extracted from producers is retained by the elite, and how much the commoners like the public uses *to* which the redistributed tribute is put. We consider President Mobutu of Zaire a kleptocrat because he keeps too much tribute (the equivalent of billions of dollars) and redistributes too little tribute (no functioning telephone system in Zaire). We consider George Washington a statesman because he spent tax money on widely admired programs and did not enrich himself as president. Nevertheless, George Washington was born into wealth, which is much more unequally distributed in the United States than in New Guinea villages.

For any ranked society, whether a chiefdom or a state, one thus has to ask: why do the commoners tolerate the transfer of the fruits of their hard labor to kleptocrats? This question, raised by political theorists from Plato to Marx, is raised anew by voters in every modern election. Kleptocracies with little public support run the risk of being overthrown, either by downtrodden commoners or by upstart would-be replacement kleptocrats seeking public support by promising a higher ratio of services rendered to fruits stolen. For example, Hawaiian history was repeatedly punctuated by revolts against repressive chiefs, usually led by younger brothers promising less oppression. This may sound funny to us in the context of old Hawaii, until we reflect on all the misery still being caused by such struggles in the modern world.

What should an elite do to gain popular support while still maintaining a more comfortable lifestyle than commoners? Kleptocrats throughout the ages have resorted to a mixture of four solutions:

1. Disarm the populace, and arm the elite. That's much easier in these days of high-tech weaponry, produced only in industrial plants and easily monopolized by an elite, than in ancient times of spears and clubs easily made at home.

2. Make the masses happy by redistributing much *of* the tribute received, in popular ways. This principle was as valid for Hawaiian chiefs as it is for American politicians today.

3. Use the monopoly of force to promote happiness, by maintaining public order and curbing violence. This is potentially a big and underappreciated advantage of centralized societies over noncentralized ones. Anthropologists formerly idealized band and tribal societies as gentle and nonviolent, because visiting anthropologists observed no murder in a band of 25 people in the course of a three-year study. Of course they didn't: it's easy to calculate that a band of a dozen adults and a dozen children, subject to the inevitable deaths occurring anyway for the usual reasons other than murder, could not perpetuate itself if in addition one of its dozen adults murdered another adult every three years. Much more extensive long-term information about band and tribal societies reveals that murder is a leading cause of death. For example, I happened to be visiting New Guinea's Iyau people at a time when a woman anthropologist was interviewing Iyau women about their life histories. Woman after woman, when asked to name her husband, named several sequential husbands who had died violent deaths. A typical answer went like this: "My first husband was killed by Elopi raiders. My second husband was killed by a man who wanted me, and who became my third husband. That husband was killed by the brother of my second husband, seeking to avenge his murder." Such biographies prove common for so-called gentle tribespeople and contributed to the acceptance of centralized authority as tribal societies grew larger.

4. The remaining way for kleptocrats to gain public support is to construct an ideology or religion justifying kleptocracy. Bands and tribes already had supernatural beliefs, just as do modern established religions, But the supernatural beliefs of bands and tribes did not serve to justify central authority, justify transfer of wealth, or maintain peace between unrelated individuals. When supernatural beliefs gained those functions and became institutionalized, they were thereby transformed into what we

term a religion. Hawaiian chiefs were typical of chiefs elsewhere, in asserting divinity, divine descent, or at least a hotline to the gods. The chief claimed to serve the people by interceding for them with the gods and reciting the ritual formulas required to obtain rain, good harvests, and success in fishing.

Chiefdoms characteristically have an ideology, precursor to an institutionalized religion, that buttresses the chief's authority. The chief may either combine the offices of political leader and priest in a single person, or may support a separate group of kleptocrats (that is, priests) whose function is to provide ideological justification for the chiefs. That is why chiefdoms devote so much collected tribute to constructing temples and other public works, which serve as centers of the official religion and visible signs of the chief's power.

Besides justifying the transfer of wealth to kleptocrats, institutionalized religion brings two other important benefits to centralized societies. First, shared ideology or religion helps solve the problem of how unrelated individuals are to live together without killing each other—by providing them with a bond not based on kinship. Second, it gives people a motive, other than genetic self-interest, for sacrificing their lives on behalf of others. At the cost of a few society members who die in battle as soldiers, the whole society becomes much more effective at conquering other societies or resisting attacks.

THE POLITICAL, ECONOMIC, and social institutions most familiar to us today are those of states, which now rule all of the world's land area except for Antarctica. Many early states and all modern ones have had literate elites, and many modern states have literate masses as well. Vanished states tended to leave visible archaeological hallmarks, such as ruins of temples with standardized designs, at least four levels of settlement sizes, and pottery styles covering tens of thousands of square miles. We thereby know that states arose around 3700 B.c. in Mesopotamia and around 300 B.C. in Mesoamerica, over 2,000 years ago in the Andes, China, and Southeast Asia, and over 1,000 years ago in West Africa. In modern times the formation of states out of chiefdoms has been observed repeatedly. Thus, we possess much more information about past states and their formation than about past chiefdoms, tribes, and bands.

Protostates extend many features of large paramount (multivillage) chiefdoms. They continue the increase in size from bands to tribes to chiefdoms. Whereas chiefdoms' populations range from a few thousand to a few tens of thousands, the populations of most modern states exceed one million, and China's exceeds one billion. The paramount chief's location may become the state's capital city. Other population centers of states outside the capital may also qualify as true cities, which are lacking in chiefdoms. Cities differ from villages in their monumental public works, palaces of rulers, accumulation of capital from tribute or taxes, and concentration of people other than food producers.

Early states had a hereditary leader with a title equivalent to king, like a super paramount chief and exercising an even greater monopoly of information, decision making, and power. Even in democracies today, crucial knowledge is available to only a few individuals, who control the flow of information to the rest of the government and consequently control decisions. For instance, in the Cuban Missile Crisis of 1963, information and discussions that determined whether nuclear war would engulf half a billion people were initially confined by President Kennedy to a ten-member executive committee of the National Security Council that he himself appointed; then he limited final decisions to a four-member group consisting of himself and three of his cabinet ministers.

Central control is more far-reaching, and economic redistribution in the form of tribute (renamed taxes) more extensive, in states than in chiefdoms. Economic specialization is more extreme, to the point where today not even farmers remain self-sufficient. Hence the effect on society is catastrophic when state government collapses, as happened in Britain upon the removal of Roman troops, administrators, and coinage between A.D. 407 and 411. Even the earliest Mesopotamian states exercised centralized control of their economies. Their food was produced by four specialist groups (cereal farmers, herders, fishermen, and orchard and garden growers), from each of which the state took the produce and to each of which it gave out the necessary supplies, tools, and foods other than the type of food that this group produced. The state supplied seeds and plow animals to the cereal farmers, took wool from the herders, exchanged the wool by long-distance trade for metal and other essential raw materials, and paid out food rations to the laborers who maintained the irrigation systems on which the farmers depended.

Many, perhaps most, early states adopted slavery on a much larger scale than did chiefdoms. That was not because chiefdoms were more kindly disposed toward defeated enemies but because the greater economic specialization of states, with more mass production and more public works, provided more uses for slave labor. In addition, the larger scale of state warfare made more captives available.

A chiefdom's one or two levels of administration are greatly multiplied in states, as anyone who has seen an organizational chart of any government knows. Along with the proliferation of vertical levels of bureaucrats, there is also horizontal specialization. Instead of konohiki carrying out every aspect of administration for a Hawaiian district, state governments have several separate departments, each with its own hierarchy, to handle water management, taxes, military draft, and so on. Even small states have more complex bureaucracies than large chiefdoms. For instance, the West African state of Maradi had a central administration with over 130 titled offices.

Internal conflict resolution within states has become increasingly formalized by laws, a judiciary, and police. The laws are often written, because many states (with conspicuous exceptions, such as that of the Incas) have had literate elites, writing having been developed around the same time as the formation of the earliest states in both Mesopotamia and Mesoamerica. In contrast, no early chiefdom not on the verge of statehood developed writing.

Early states had state religions and standardized temples. Many early kings were considered divine and were accorded special treatment in innumerable respects. For example, the Aztec and Inca emperors were both carried about in litters; servants went ahead of the Inca emperor's litter and swept the ground clear; and the Japanese language includes special forms of the pronoun "you" for use only in addressing the emperor. Early kings were themselves the head of the state religion or else had separate high priests. The Mesopotamian temple was the center not only of religion but also of economic redistribution, writing, and crafts technology.

All these features of states carry to an extreme the developments that led from tribes to chiefdoms. In addition, though, states have diverged from chiefdoms in several new directions. The most fundamental such distinction is that states are organized on political and territorial lines, not on the kinship lines that defined bands, tribes, and simple chiefdoms. Furthermore, bands and tribes always, and chiefdoms usually, consist of a single **ethnic and** linguistic group. States, though—especially so-called empires formed by amalgamation or conquest of states—are regularly multiethnic and multilingual. State bureaucrats are not selected mainly on the basis of kinship, as in chiefdoms, but are professionals selected at least partly on the basis of training and ability. In later states, including most today, the leadership often became nonhereditary, and many states abandoned the entire system of formal hereditary classes carried over from chiefdoms.

OVER THE PAST 13,000 years the predominant trend in human society has been the replacement of smaller, less complex units by larger, more complex ones. Obviously, that is no more than an average long-term trend, with innumerable shifts in either direction: 1,000 amalgamations for *999* reversals. We know from our daily newspaper that large units (for instance, the former USSR, Yugoslavia, and Czechoslovakia) can disintegrate into smaller units, as did Alexander of Macedon's empire over 2,000 years ago. More complex units don't always conquer less complex ones but may succumb to them, as when the Roman and Chinese Empires were overrun by "barbarian" and Mongol chiefdoms, respectively. But the long-term trend has still been toward large, complex societies, culminating in states.

Obviously, too, part of the reason for states' triumphs over simpler entities when the two collide is that states usually enjoy an advantage of weaponry and other technology, and a large numerical advantage in population. But there are also two other potential advantages inherent in chiefdoms and states. First, a centralized decision maker has the advantage at concentrating troops and resources. Second, the official religions and patriotic fervor of many states make their troops willing to fight suicidally.

The latter willingness is one so strongly programmed into us citizens of modern states, by our schools and churches and governments, that we forget what a radical break it marks with previous human history. Every state has its slogan urging its citizens to be prepared to die if necessary for the state: Britain's "For King and Country," Spain's "Por Dios y Espana," and so on. Similar sentiments motivated 16th-century Aztec warriors: "There is nothing like death in war, nothing like the flowery death so precious to Him [the Aztec national god Huitzilopochtli] who gives life: far off I see it, my heart yearns for it!"

Such sentiments are unthinkable in bands and tribes. In all the accounts that my New Guinea friends have given me of their former tribal wars, there has been not a single hint of tribal patriotism, of a suicidal charge, or of any other military conduct carrying an accepted risk of being killed. Instead, raids are initiated by ambush or by superior force, so as to minimize at all costs the risk that one might die for one's village. But that attitude severely limits the military options of tribes, compared with state societies. Naturally, what makes patriotic and religious fanatics such dangerous opponents is not the deaths of the fanatics themselves, but their willingness to accept the deaths of a fraction of their number in order to annihilate or crush their infidel enemy. Fanaticism in war, of the type that drove recorded Christian and Islamic conquests, was probably unknown on Earth until chiefdoms and especially states emerged within the last 6,000 years.

HOW DID SMALL, noncentralized, kin-based societies evolve into large centralized ones in which most members are not closely related to each other? Having reviewed the stages in this transformation from bands to states, we now ask what impelled societies thus to transform themselves.

At many moments in history, states have arisen independently—or, as cultural anthropologists say, "pristinely," that is, in the absence of any preexisting surrounding states. Pristine state origins took place at least once, possibly many times, on each of the continents except Australia and North America. Prehistoric states included those of Mesopotamia, North China, the Nile and Indus Valleys, Mesoamerica, the Andes, and West Africa. Native states in contact with European states have arisen from chiefdoms repeatedly in the last three centuries in Madagascar, Hawaii, Tahiti, and many parts of Africa. Chiefdoms have arisen pristinely even more often, in all of the same regions and in North America's Southeast and Pacific Northwest, the Amazon, Polynesia, and sub-Saharan Africa. All these origins of complex societies give us a rich database for understanding their development.

Of the many theories addressing the problem of state origins, the simplest denies that there is any problem to solve. Aristotle considered states the natural condition of human society, requiring no explanation. His error was understandable, because all the societies with which he would have been acquainted—Greek societies of the fourth century B.C.—were states. However, we now know that, as of A.D. 1492, much of the world was instead organized into chiefdoms, tribes, or bands. State formation does demand an explanation.

The next theory is the most familiar one. The French philosopher Jean-Jacques Rousseau speculated that states are formed by a social contract, a rational decision reached when people calculated their self-interest, came to the agreement that they would be better off in a state than in simpler societies, and voluntarily did away with their simpler societies. But observation and historical records have failed to uncover a single case of a state's being formed in that ethereal atmosphere of dispassionate farsightedness. Smaller units do not voluntarily abandon their sovereignty and merge into larger units. They do so only by conquest, or under external duress.

A third theory, still popular with some historians and economists, sets out from the undoubted fact that, in both Mesopotamia and North China and Mexico, large-scale irrigation systems began to be constructed around the time that states started to emerge. The theory also notes that any big, complex system for irrigation or hydraulic management requires a centralized bureaucracy to construct and maintain it. The theory then turns an observed rough correlation in time into a postulated chain of cause and effect. Supposedly, Mesopotamians and North Chinese and Mexicans foresaw the advantages that a large-scale irrigation system would bring them, even though there was at the time no such system within thousands of miles (or anywhere on Earth) to illustrate for them those advantages. Those farsighted people chose to merge their inefficient little chiefdoms into a larger state capable of blessing them with large-scale irrigation.

However, this "hydraulic theory" of state formation is subject to the same objections leveled against social contract theories in general. More specifically, it addresses only the final stage in the evolution of complex societies. It says nothing about what drove the progression from bands to tribes to chiefdoms during all the millennia before the prospect of large-scale irrigation loomed up on the horizon. When historical or archaeological dates are examined in detail, they fail to support the view of irrigation as the driving force for state formation. In Mesopotamia, North China, Mexico, and Madagascar, small-scale irrigation systems already existed before the rise of states. Construction of large-scale irrigation systems did not accompany the emergence of states but came only significantly later in each of those areas. In most of the states formed over the Maya area of

Mesoamerica and the Andes, irrigation systems always remained small-scale ones that local communities could build and maintain themselves. Thus, even in those areas where complex systems of hydraulic management did emerge, they were a secondary consequence of states that must have formed for other reasons.

What seems to me to point to a fundamentally correct view of state formation is an undoubted fact of much wider validity than the correlation between irrigation and the formation of some states—namely, that the size of the regional population is the strongest single predictor of societal complexity. As we have seen, bands number a few dozen individuals, tribes a few hundred, chiefdoms a few thousand to a few tens of thousands, and states generally over about 50,000. In addition to that coarse correlation between regional population size and type of society (band, tribe, and so on), there is a finer trend, within each of those categories, between population and societal complexity: for instance, that chiefdoms with large populations prove to be the most centralized, stratified, and complex ones.

These correlations suggest strongly that regional population size or population density or population pressure has *something* to do with the formation of complex societies. But the correlations do not tell us precisely how population variables function in a chain of cause and effect whose outcome is a complex society. To trace out that chain, let us now remind ourselves how large dense populations themselves arise. Then we can examine why a large but simple society could not maintain itself. With that as background, we shall finally return to the question of how a simpler society actually becomes more complex as the regional population increases.

WE HAVE SEEN that large or dense populations arise only under conditions of food production, or at least under exceptionally productive conditions for hunting-gathering. Some productive hunter-gatherer societies reached the organizational level of chiefdoms, but none reached the level of states: all states nourish their citizens by food production. These considerations, along with the just mentioned correlation between regional population size and societal complexity, have led to a protracted chicken-or-egg debate about the causal relations between food production, population variables, and societal complexity. Is it intensive food production that is the cause, triggering population growth and somehow leading to a complex society? Or are large populations and complex societies instead the cause, somehow leading to intensification of food production?

Posing the question in that either-or form misses the point. Intensified food production and societal complexity stimulate each other, by autocatalysis. That is, population growth leads to societal complexity, by mechanisms that we shall discuss, while societal complexity in turn leads to intensified food production and thereby to population growth. Complex centralized societies are uniquely capable of organizing public works (including irrigation systems), long-distance trade (including the importation of metals to make better agricultural tools), and activities of different groups of economic specialists (such as feeding herders with farmers' cereal, and transferring the herders' livestock to farmers for use as plow animals). All of these capabilities of centralized societies have fostered intensified food production and hence population growth throughout history.

In addition, food production contributes in at least three ways to specific features of complex societies. First, it involves seasonally pulsed inputs of labor. When the harvest has been stored, the farmers' labor becomes available for a centralized political authority to harness—in order to build public works advertising state power (such as the Egyptian pyramids), or to build public works that could feed more mouths (such as Polynesian Hawaii's irrigation systems or fishponds), or to undertake wars of conquest to form larger political entities.

Second, food production may be organized so as to generate stored food surpluses, which permit economic specialization and social stratification. The surpluses can be used to feed all tiers of a complex society: the chiefs, bureaucrats, and other members of the elite; the scribes, craftspeople, and other non-food-producing specialists; and the farmers themselves, during times that they are drafted to construct public works.

Finally, food production permits or requires people to adopt sedentary living, which is a prerequisite for accumulating substantial possessions, developing elaborate technology and crafts, and constructing public works. The importance of fixed residence to a complex society explains why missionaries and governments, whenever they make first contact with previously uncontacted nomadic tribes or bands in New Guinea or the Amazon, universally have two immediate goals. One goal, of course, is the obvious one of "pacifying" the nomads: that is, dissuading them from killing missionaries, bureaucrats, or each other. The other goal is to induce the nomads to settle in villages, so that the missionaries and bureaucrats can find the nomads, bring them services such as medical care and schools, and proselytize and control them.

THUS, FOOD PRODUCTION, which increases population size, also acts in many ways to make features of complex societies *possible.* But that doesn't prove that food production and large populations make complex societies *inevitable.* How can we account for the empirical observation that band or tribal organization just does not work for societies of hundreds of thousands of people, and that all existing large societies have complex centralized organization? We can cite at least four obvious reasons.

One reason is the problem of conflict between unrelated strangers. That problem grows astronomically as the number of people making up the society increases. Relationships within a band of 20 people involve only 190 two-person interactions (20 people times 19 divided by 2), but a band of 2,000 would have 1,999,000 dyads. Each of those dyads represents a potential time bomb that could explode in a murderous argument. Each murder in band and tribal societies usually leads to an attempted revenge killing, starting one more unending cycle of murder and countermurder that destabilizes the society.

In a band, where everyone is closely related to everyone else, people related simultaneously to both quarreling parties step in to mediate quarrels. In a tribe, where many people are still close relatives and everyone at least knows everybody else by name, mutual relatives and mutual friends mediate the quarrel. But once the threshold of "several hundred," below which everyone can know everyone else, has been crossed, increasing numbers of dyads become pairs of unrelated strangers. When strangers fight, few people present will be friends or relatives of both combatants, with self-interest in stopping the fight. Instead, many onlookers will be friends or relatives of only one combatant and will side with that person, escalating the two-person fight into a general brawl. Hence a large society that continues to leave conflict resolution to all of its members is guaranteed to blow up. That factor alone would explain why societies of thousands can exist only if they develop centralized authority to monopolize force and resolve conflicts.

A second reason is the growing impossibility of communal decision making with increasing population size. Decision making by the entire adult population is still possible in New Guinea villages small enough that news and information quickly spread to everyone, that everyone can hear everyone else in a meeting of the whole village, and that everyone who wants to speak at the meeting has the opportunity to do so. But all those prerequisites for communal decision making become unattainable in much larger communities. Even now, in these days of microphones and loudspeakers, we all know that a group meeting is no way to resolve issues for a group of thousands of people. Hence a large society must be structured and centralized if it is to reach decisions effectively.

A third reason involves economic considerations. Any society requires means to transfer goods between its members. One individual may happen to acquire more of some essential commodity on one day and less on another. Because individuals have different talents, one individual consistently tends to wind up with an excess of some essentials and a deficit of others. In small societies with few pairs of members, the resulting necessary transfers of goods can be arranged directly between pairs of individuals or families, by reciprocal exchanges. But the same mathematics that makes direct pairwise conflict resolution inefficient in large societies makes direct pairwise economic transfers also inefficient. Large societies can function economically only if they have a redistributive economy in addition to a reciprocal economy. Goods in excess of an individual's needs must be transferred from the individual to a centralized authority, which then redistributes the goods to individuals with deficits.

A final consideration mandating complex organization for large societies has to do with population densities. Large societies of food producers have not only more members but also higher population densities than do small bands of hunter-gatherers. Each band of a few dozen hunters occupies a large territory, within which they can acquire most of the resources essential to them. They can obtain their remaining necessities by trading with neighboring bands during intervals between band warfare. As population density increases, the territory of that band-sized population of a few dozen would shrink to a small area, with more and more of life's necessities having to be obtained outside the area. For instance, one couldn't just divide Holland's 16,000 square miles and 16,000,000 people into 800,000 individual territories, each encompassing 13 acres and serving as home to an autonomous band of 20 people who remained self-sufficient confined within their 13 acres, occasionally taking advantage of a temporary truce to come to the borders of their tiny territory in order to exchange some trade items and brides with the next band. Such spatial realities require that densely populated regions support large and complexly organized societies.

Considerations of conflict resolution, decision making, economics, and space thus converge in requiring large societies to be centralized. But centralization of power inevitably opens the door—for those who hold the power, are privy to information, make the decisions, and redistribute the goods—to exploit the resulting opportunities to reward themselves and their relatives. To anyone familiar with any modern grouping of people, that's obvious. As early societies developed, those acquiring centralized power gradually established themselves as an elite, perhaps originating as one of several formerly equal-ranked village clans that became "more equal" than the others.

THOSE ARE THE reasons why large societies cannot function with band organization and instead are complex kleptocracies. But we are still left with the question of how small, simple societies actually evolve or amalgamate into large, complex ones. Amalgamation, centralized conflict resolution, decision making, economic redistribution, and kleptocratic religion don't just develop automatically through a Rousseauesque social contract. What drives the amalgamation?

In part, the answer depends upon evolutionary reasoning. I said at the outset of this chapter that societies classified in the same category are not all identical to each other, because humans and human groups are infinitely diverse. For example, among bands and tribes, the big-men of some are inevitably more charismatic, powerful, and skilled in reaching decisions than the big-men of others. Among large tribes, those with stronger big-men and hence greater centralization tend to have an advantage over those with less centralization. Tribes that resolve conflicts as poorly as did the Fayu tend to blow apart again into bands, while ill-governed chiefdoms blow apart into smaller chiefdoms or tribes. Societies with effective conflict resolution, sound decision making, and harmonious economic redistribution can develop better technology, concentrate their military power, seize larger and more productive territories, and crush autonomous smaller societies one by one.

Thus, competition between societies at one level of complexity tends to lead to societies on the next level of complexity if conditions permit. Tribes conquer or combine with tribes to reach the size of chiefdoms, which conquer or combine with other chiefdoms to reach the size of states, which conquer or combine with other states to become empires. More generally, large units potentially enjoy an advantage over individual small units if—and that's a big "if"—the large units can solve the problems that come with their larger size, such as perennial threats from upstart claimants to leadership, commoner resentment of kleptocracy, and increased problems associated with economic integration.

The amalgamation of smaller units into larger ones has often been documented historically or archaeologically. Contrary to Rousseau, such amalgamations never occur by a process of unthreatened little societies freely deciding to merge, in order to promote the happiness of their citizens. Leaders of little societies, as of big ones, are jealous of their independence and prerogatives. Amalgamation occurs instead in either of two ways: by merger under the threat of external force, or by actual conquest. Innumerable examples are available to illustrate each mode of amalgamation.

Merger under the threat of external force is well illustrated by the formation of the Cherokee Indian confederation in the U.S. Southeast. The Cherokees were originally divided into 30 or 40 independent chiefdoms, each consisting of a village of about 400 people. Increasing white settlement led to conflicts between Cherokees and whites. When individual Cherokees robbed or assaulted white settlers and traders, the whites were unable to discriminate among the different Cherokee chiefdoms and retaliated indiscriminately against any Cherokees, either by military action or by cutting off trade. In response, the Cherokee chiefdoms gradually found themselves compelled to join into a single confederacy in the course of the 18th century. Initially, the larger chiefdoms in 1730 chose an overall leader, a chief named Moytoy, who was succeeded in 1741 by his son. The first task of these leaders was to punish individual Cherokees who attacked whites, and to deal with the white government. Around 1758 the Cherokees regularized their decision making with an annual council modeled on previous village councils and meeting at one village (Echota), which thereby became a de facto "capital." Eventually, the Cherokees became literate (as we saw in Chapter 12) and adopted a written constitution.

The Cherokee confederacy was thus formed not by conquest but by the amalgamation of previously jealous smaller entities, which merged only when threatened with destruction by powerful external forces. In much the same way, in an example of state formation described in every American history textbook, the white American colonies themselves, one of which (Georgia) had precipitated the formation of the Cherokee state, were impelled to form a nation of their own when threatened with the powerful external force of the British monarchy. The American colonies were initially as jealous of their autonomy as the Cherokee chiefdoms, and their first attempt at amalgamation under the Articles of Confederation (1781) proved unworkable because it reserved too much autonomy to the ex-colonies. Only further threats, notably Shays's Rebellion of 1786 and the unsolved burden of war debt, overcame the ex-colonies' extreme reluctance to sacrifice autonomy and pushed them into adopting our current strong federal constitution in 1787. The 19th-century unification of Germany's jealous principalities proved equally difficult. Three early attempts (the Frankfurt Parliament of 1848, the restored German Confederation of 1850, and the North German Confederation of 1866) failed before the external threat of France's declaration of war in 1870 finally led to the princelets' surrendering much of their power to a central imperial German government in 1871.

The other mode of formation of complex societies, besides merger under threat of external force, is merger by conquest. A well-documented example is the origin of the Zulu state, in southeastern Africa. When first observed by white settlers, the Zulus were divided into dozens of little chiefdoms. During the late 1700s, as population pressure rose, fighting between the chiefdoms became increasingly intense. Among all those chiefdoms, the ubiquitous problem of devising centralized power structures was solved most successfully by a chief called Dingiswayo, who gained ascendancy of the Mtetwa chiefdom by killing a rival around 1807. Dingiswayo developed a superior centralized military organization by drafting young men from all villages and grouping them into regiments by age rather than by their village. He also developed superior centralized political organization by abstaining from slaughter as he conquered other chiefdoms, leaving the conquered chief's family intact, and limiting himself to replacing the conquered chief himself with a relative willing to cooperate with Dingiswayo. He developed superior centralized conflict resolution by expanding the adjudication of quarrels. In that way Dingiswayo was able to conquer and begin the integration of 30 other Zulu chiefdoms. His successors strengthened the resulting embryonic Zulu state by expanding its judicial system, policing, and ceremonies.

This Zulu example of a state formed by conquest can be multiplied almost indefinitely. Native states whose formation from chiefdoms happened to be witnessed by Europeans in the 18th and 19th centuries include the Polynesian Hawaiian state, the Polynesian Tahitian state, the Merina state of Madagascar, Lesotho and Swazi and other southern African states besides that of the Zulus, the Ashanti state of West Africa, and the Ankole and Buganda states of Uganda. The Aztec and Inca Empires were formed by 15th-century conquests, before Europeans arrived, but we know much about their formation from Indian oral histories transcribed by early Spanish settlers. The formation of the Roman state and the expansion of the Macedonian Empire under Alexander were described in detail by contemporary classical authors.

All these examples illustrate that wars, or threats of war, have played a key role in most, if not all, amalgamations of societies. But wars, even between mere bands, have been a constant fact of human history. Why is it, then, that they evidently began causing amalgamations of societies only within the past 13,000 years? We had already concluded that the formation of complex societies is somehow linked to population pressure, so we should now seek a link between population pressure and the outcome of war. Why should wars tend to cause amalgamations of societies when populations are dense but not when they are sparse? The answer is that the fate of defeated peoples depends on population density, with three possible outcomes:

Where population densities are very low, as is usual in regions occupied by hunter-gatherer bands, survivors of a defeated group need only move farther away from their enemies. That tends to be the result of wars between nomadic bands in New Guinea and the Amazon.

Where population densities are moderate, as in regions occupied by food-producing tribes, no large vacant areas remain to which survivors of a defeated band can flee. But tribal societies without intensive food production have no employment for slaves and do not produce large enough food surpluses to be able to yield much tribute. Hence the victors have no use for survivors of a defeated tribe, unless to take the women in marriage. The defeated men are killed, and their territory may be occupied by the victors.

Where population densities are high, as in regions occupied by states or chiefdoms, the defeated still have nowhere to flee, but the victors now have two options for exploiting them while leaving them alive. Because chiefdoms and state societies have economic specialization, the defeated can be used as slaves, as commonly happened in biblical times. Alternatively, because many such societies have intensive food production systems capable of yielding large surpluses, the victors can leave the defeated in place but deprive them of political autonomy, make them pay regular tribute in food or goods, and amalgamate their society into the victorious state or chiefdom. This has been the usual outcome of battles associated with the founding of states or empires throughout recorded history. For example, the Spanish conquistadores wished to exact tribute from Mexico's defeated native populations, so they were very interested in the Aztec Empire's tribute lists. It turned out that the tribute received by the Aztecs each year from subject peoples had included 7,000 tons of corn, 4,000 tons of beans, 4,000 tons of grain amaranth, 2,000,000 cotton cloaks, and huge quantities of cacao beans, war costumes, shields, feather headdresses, and amber.

Thus, food production, and competition and diffusion between societies, led as ultimate causes, via chains of causation that differed in detail but that all involved large dense populations and sedentary living, to the proximate agents of conquest: germs, writing, technology, and centralized political organization. Because those ultimate causes developed differently on different continents, so did those agents of conquest. Hence those agents tended to arise in association with each other, but the association was not strict: for example, an empire arose without writing among the Incas, and writing with few epidemic diseases among the Aztecs. Dingiswayo's Zulus illustrate that each of those agents contributed somewhat independently to history's pattern. Among the dozens of Zulu chiefdoms, the Mtetwa chiefdom enjoyed no advantage whatsoever of technology, writing, or germs over the other chiefdoms, which it nevertheless succeeded in defeating. Its advantage lay solely in the spheres of government and ideology. The resulting Zulu state was thereby enabled to conquer a fraction of a continent for nearly a century.

YALI'S QUESTION WENT TO THE HEART OF THE CURRENT human condition, and of post-Pleistocene human history. Now that we have completed this brief tour over the continents, how shall we answer Yali?

I would say to Yali: the striking differences between the long-term histories of peoples of the different continents have been due not to innate differences in the peoples themselves but to differences in their environments. I expect that if the populations of Aboriginal Australia and Eurasia could have been interchanged during the Late Pleistocene, the original Aboriginal Australians would now be the ones occupying most of the Americas and Australia, as well as Eurasia, while the original Aboriginal Eurasians would be the ones now reduced to downtrodden population fragments in Australia. One might at first be inclined to dismiss this assertion as meaningless, because the experiment is imaginary and my claim about its outcome cannot be verified. But historians are nevertheless able to evaluate related hypotheses by retrospective tests. For instance, one can examine what did happen when European farmers were transplanted to Greenland or the U.S. Great Plains, and when farmers stemming ultimately from China emigrated to the Chatham Islands, the rain forests of Borneo, or the volcanic soils of Java or Hawaii. These tests confirm that the same ancestral peoples either ended up extinct, or returned to living as hunter-gatherers, or went on to build complex states, depending on their environments. Similarly, Aboriginal Australian hunter-gatherers, variously transplanted to Flinders Island, Tasmania, or southeastern Australia, ended up extinct, or as hunter-gatherers with the modern world's simplest technology, or as canal builders intensively managing a productive fishery, depending on their environments.

Of course, the continents differ in innumerable environmental features affecting trajectories of human societies. But a mere laundry list of every possible difference does not constitute an answer to Yali's question. Just four sets of differences appear to me to be the most important ones.

The first set consists of continental differences in the wild plant and animal species available as starting materials for domestication. That's because food production was critical for the accumulation of food surpluses that could feed non-food-producing specialists, and for the buildup of large populations enjoying a military advantage through mere numbers even before they had developed any technological or political advantage. For both of those reasons, all developments of economically complex, socially stratified, politically centralized societies beyond the level of small nascent chiefdoms were based on food production.

But most wild animal and plant species have proved unsuitable for domestication: food production has been based on relatively few species of livestock and crops. It turns out that the number of wild candidate species for domestication varied greatly among the continents, because of differences in continental areas and also (in the case of big mammals) in Late Pleistocene extinctions. These extinctions were much more severe in Australia and the Americas than in Eurasia or Africa. As a result, Africa ended up biologically somewhat less well endowed than the much larger Eurasia, the Americas still less so, and Australia even less so, as did Yali's New Guinea (with one-seventieth of Eurasia's area and with all of its original big mammals extinct in the Late Pleistocene).

On each continent, animal and plant domestication was concentrated in a few especially favorable homelands accounting for only a small fraction of the continent's total area. In the case of technological innovations and political institutions as well, most societies acquire much more from other societies than they invent themselves. Thus, diffusion and migration within a continent contribute importantly to the development of its societies, which tend in the long run to share each other's developments (insofar as environments permit) because of the processes illustrated in such simple form by Maori New Zealand's Musket Wars. That is, societies initially lacking an advantage either acquire it from societies possessing it or (if they fail to do so) are replaced by those other societies.

Hence a second set of factors consists of those affecting rates of diffusion and migration, which differed greatly among continents. They were most rapid in Eurasia, because of its east-west major axis and its relatively modest ecological and geographical barriers. The reasoning is straightforward for movements of crops and livestock, which depend strongly on climate and hence on latitude. But similar reasoning also applies to the diffusion of technological innovations, insofar as they are best suited without modification to specific environments. Diffusion was slower in Africa and especially in the Americas, because of those continents' north-south major axes and geographic and ecological barriers. It was also difficult in traditional New Guinea, where rugged terrain and the long backbone of high mountains prevented any significant progress toward political and linguistic unification.

Related to these factors affecting diffusion *within* continents is a third set of factors influencing diffusion *between* continents, which may also help build up a local pool of domesticates and technology. Ease of intercontinental diffusion has varied, because some continents are more isolated than others. Within the last 6,000 years it has been easiest from Eurasia to sub-Saharan Africa, supplying most of Africa's species of livestock. But interhemispheric diffusion made no contribution to Native America's complex societies, isolated from Eurasia at low latitudes by broad oceans, and at high latitudes by geography and by a climate suitable just for hunting-gathering. To Aboriginal Australia, isolated from Eurasia by the water barriers of the Indonesian Archipelago, Eurasia's sole proven contribution was the dingo.

The fourth and last set of factors consists of continental differences in area or total population size. A larger area or population means more potential inventors, more competing societies, more innovations available to adopt—and more pressure to adopt and retain innovations, because societies failing to do so will tend to be eliminated by competing societies. That fate befell African pygmies and many other hunter-gatherer populations displaced by farmers. Conversely, it also befell the stubborn, conservative Greenland Norse farmers, replaced by Eskimo hunter-gatherers whose subsistence methods and technology were far superior to those of the Norse under Greenland conditions. Among the world's landmasses, area and the number of competing societies were largest for Eurasia, much smaller for Australia and New Guinea and especially for Tasmania. The Americas, despite their large aggregate area, were fragmented by geography and ecology and functioned effectively as several poorly connected smaller continents.

Those four sets of factors constitute big environmental differences that can be quantified objectively and that are not subject to dispute. While one can contest my subjective impression that New Guineans are on the average smarter than Eurasians, one cannot deny that New Guinea has a much smaller area and far fewer big animal species than Eurasia. But mention of these environmental differences invites among historians the label "geographic determinism," which raises hackles. The label seems to have unpleasant connotations, such as that human creativity counts for nothing, or that we humans are passive robots helplessly programmed by climate, fauna, and flora. Of course these fears are misplaced. Without human inventiveness, all of us today would still be cutting our meat with stone tools and eating it raw, like our ancestors of a million years ago. All human societies contain inventive people. It's just that some environments provide more starting materials, and more favorable conditions for utilizing inventions, than do other environments.

THESE ANSWERS TO Yali's question are longer and more complicated than Yali himself would have wanted. Historians, however, may find them too brief and oversimplified. Compressing 13,000 years of history on all continents into a 400-page book works out to an average of about one page per continent per 150 years, making brevity and simplification inevitable. Yet the compression brings a compensating benefit: long-term comparisons of regions yield insights that cannot be won from short-term studies of single societies.

Naturally, a host of issues raised by Yali's question remain unresolved. At present, we can put forward some partial answers plus a research agenda for the future, rather than a fully developed theory. The challenge now is to develop human history as a science, on a par with acknowledged historical sciences such as astronomy, geology, and evolutionary biology. Hence it seems appropriate to conclude this book by looking to the future of the discipline of history, and by outlining some of the unresolved issues.

The most straightforward extension of this book will be to quantify further, and thus to establish more convincingly the role of, intercontinental differences in the four sets of factors that appear to be most important. To illustrate differences in starting materials for domestication, I provided numbers for each continent's total of large wild terrestrial mammalian herbivores and omnivores (Table 9.2) and of large-seeded cereals (Table 8.1). One extension would be to assemble corresponding numbers for large-seeded legumes (pulses), such as beans, peas, and vetches. In addition, I mentioned factors disqualifying big mammalian candidates for domestication, but I did not tabulate how many candidates are disqualified by each factor on each continent. It would be interesting to do so, especially for Africa, where a higher percentage of candidates is disqualified than in Eurasia: which disqualifying factors are most important in Africa, and what has selected for their high frequency in African mammals? Quantitative data should also be assembled to test my preliminary calculations suggesting differing rates of diffusion along the major axes of Eurasia, the Americas, and Africa.

A SECOND EXTENSION will be to smaller geographic scales and shorter time scales than those of this book. For instance, the following obvious question has probably occurred to readers already: why, within Eurasia, were European societies, rather than those of the Fertile Crescent or China or India, the ones that colonized America and Australia, took the lead in technology, and became politically and economically dominant in the modern world? A historian who had lived at any time between 8500 B.C. and A.D. 1450, and who had tried then to predict future historical trajectories, would surely have labeled Europe's eventual dominance as the least likely outcome, because Europe was the most backward of those three Old World regions for most of those 10,000 years. From 8500 B.c. until the rise of Greece and then Italy after 500 B.C., almost all major innovations in western Eurasia—animal domestication, plant domestication, writing, metallurgy, wheels, states, and so on—arose in or near the Fertile Crescent. Until the proliferation of water mills after about A.D. 900, Europe west or north of the Alps contributed nothing of significance to Old World technology or civilization; it was instead a recipient of developments from the eastern Mediterranean, Fertile Crescent, and China. Even from A.D. 1000 to 1450 the flow of science and technology was predominantly into

Europe from the Islamic societies stretching from India to North Africa, rather than vice versa. During those same centuries China led the world in technology, having launched itself on food production nearly as early as the Fertile Crescent did.

Why, then, did the Fertile Crescent and China eventually lose their enormous leads of thousands of years to late-starting Europe? One can, of course, point to proximate factors behind Europe's rise: its development of a merchant class, capitalism, and patent protection for inventions, its failure to develop absolute despots and crushing taxation, and its Greco-Judeo-Christian tradition of critical empirical inquiry. Still, for all such proximate causes one must raise the question of ultimate cause: why did these proximate factors themselves arise in Europe, rather than in China or the Fertile Crescent?

For the Fertile Crescent, the answer is clear. Once it had lost the head start that it had enjoyed thanks to its locally available concentration of domesticable wild plants and animals, the Fertile Crescent possessed no further compelling geographic advantages. The disappearance of that head start can be traced in detail, as the westward shift in powerful empires. After the rise of Fertile Crescent states in the fourth millennium B.c., the center of power initially remained in the Fertile Crescent, rotating between empires such as those of Babylon, the Hittites, Assyria, and Persia. With the Greek conquest of all advanced societies from Greece east to India under Alexander the Great in the late fourth century B.C., power finally made its first shift irrevocably westward. It shifted farther west with Rome's conquest of Greece in the second century B.c., and after the fall of the Roman Empire it eventually moved again, to western and northern Europe.

The major factor behind these shifts becomes obvious as soon as one compares the modern Fertile Crescent with ancient descriptions of it. Today, the expressions "Fertile Crescent" and "world leader in food production" are absurd. Large areas of the former Fertile Crescent are now desert, semidesert, steppe, or heavily eroded or salinized terrain unsuited for agriculture. Today's ephemeral wealth of some of the region's nations, based on the single nonrenewable resource of oil, conceals the region's long-standing fundamental poverty and difficulty in feeding itself.

In ancient times, however, much of the Fertile Crescent and eastern Mediterranean region, including Greece, was covered with forest. The region's transformation from fertile woodland to eroded scrub or desert has been elucidated by paleobotanists and archaeologists. Its woodlands were cleared for agriculture, or cut to obtain construction timber, or burned as firewood or for manufacturing plaster. Because of low rainfall and hence low primary productivity (proportional to rainfall), regrowth of vegetation could not keep pace with its destruction, especially in the presence of overgrazing by abundant goats. With the tree and grass cover removed, erosion proceeded and valleys silted up, while irrigation agriculture in the low-rainfall environment led to salt accumulation. These processes, which began in the Neolithic era, continued into modern times. For instance, the last forests near the ancient Nabataean capital of Petra, in modern Jordan, were felled by the Ottoman Turks during construction of the Hejaz railroad just before World War I.

Thus, Fertile Crescent and eastern Mediterranean societies had the misfortune to arise in an ecologically fragile environment. They committed ecological suicide by destroying their own resource base. Power shifted westward as each eastern Mediterranean society in turn undermined itself, beginning with the oldest societies, those in the east (the Fertile Crescent). Northern and western Europe has been spared this fate, not because its inhabitants have been wiser but because they have had the good luck to live in a more robust environment with higher rainfall, in which vegetation regrows quickly. Much of northern and western Europe is still able to support productive intensive agriculture today, 7,000 years after the arrival of food production. In effect, Europe received its crops, livestock, technology, and writing systems from the Fertile Crescent, which then gradually eliminated itself as a major center of power and innovation.

That is how the Fertile Crescent lost its huge early lead over Europe. Why did China also lose its lead? Its falling behind is initially surprising, because China enjoyed undoubted advantages: a rise of food production nearly as early as in the Fertile Crescent; ecological diversity from North to South China and from the coast to the high mountains of the Tibetan plateau, giving rise to a diverse set of crops, animals, and technology; a large and productive expanse, nourishing the largest regional human population in the world; and an environment less dry or ecologically fragile than the Fertile Crescent's, allowing China still to support productive intensive agriculture after nearly 10,000 years, though its environmental problems are increasing today and are more serious than western Europe's.

These advantages and head start enabled medieval China to lead the world in technology. The long list of its major technological firsts includes cast iron, the compass, gunpowder, paper, printing, and many others mentioned earlier. It also led the world in political power, navigation, and control of the seas. In the early 15th century it sent treasure fleets, each consisting of hundreds of ships up to 400 feet long and with total crews of up to 28,000, across the Indian Ocean as far as the east coast of Africa, decades before Columbus's three puny ships crossed the narrow Atlantic Ocean to the Americas' east coast. Why didn't Chinese ships proceed around Africa's southern cape westward and colonize Europe, before Vasco da Gama's own three puny ships rounded the Cape of Good Hope eastward and launched Europe's colonization of East Asia? Why didn't Chinese ships cross the Pacific to colonize the Americas' west coast? Why, in brief, did China lose its technological lead to the formerly so backward Europe?

The end of China's treasure fleets gives us a clue. Seven of those fleets sailed from China between A.D. 1405 and 1433. They were then suspended as a result of a typical aberration of local politics that could happen anywhere in the world: a power struggle between two factions at the Chinese court (the eunuchs and their opponents). The former faction had been identified with sending and captaining the fleets. Hence when the latter faction gained the upper hand in a power struggle, it stopped sending fleets, eventually dismantled the shipyards, and forbade oceangoing shipping. The episode is reminiscent of the legislation that strangled development of public electric lighting in London in the 1880s, the isolationism of the United States between the First and Second World Wars, and any number of backward steps in any number of countries, all motivated by local political issues. But in China there was a difference, because the entire region was politically unified. One decision stopped fleets over the whole of China. That one temporary decision became irreversible, because no shipyards remained to turn out ships that would prove the folly of that temporary decision, and to serve as a focus for rebuilding other shipyards.

Now contrast those events in China with what happened when fleets of exploration began to sail from politically fragmented Europe. Christopher Columbus, an Italian by birth, switched his allegiance to the duke of Anjou in France, then to the king of Portugal. When the latter refused his request for ships in which to explore westward, Columbus turned to the duke of Medina-Sedonia, who also refused, then to the count of Medina-Celi, who did likewise, and finally to the king and queen of Spain, who denied Columbus's first request but eventually granted his renewed appeal. Had

Europe been united under any one of the first three rulers, its colonization of the Americas might have been stillborn.

In fact, precisely because Europe was fragmented, Columbus succeeded on his fifth try in persuading one of Europe's hundreds of princes to sponsor him. Once Spain had thus launched the European colonization of America, other European states saw the wealth flowing into Spain, and six more joined in colonizing America. The story was the same with Europe's cannon, electric lighting, printing, small firearms, and innumerable other innovations: each was at first neglected or opposed in some parts of Europe for idiosyncratic reasons, but once adopted in one area, it eventually spread to the rest of Europe.

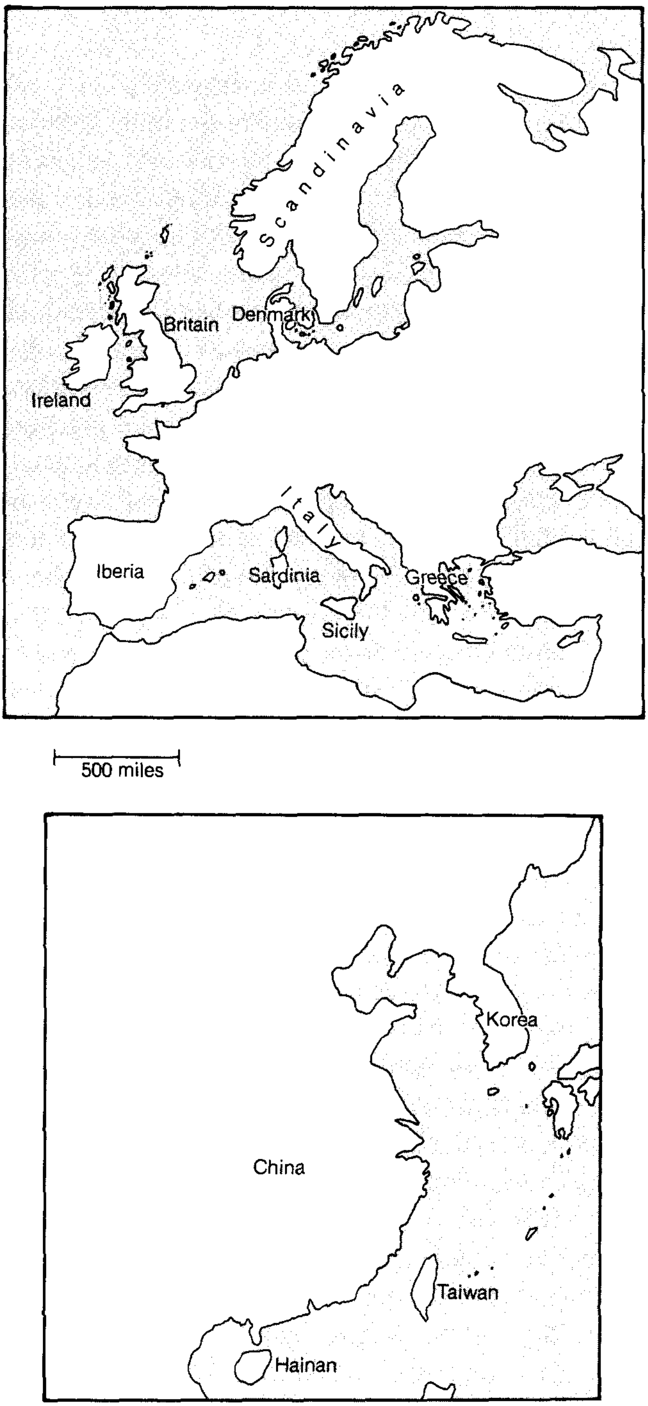
These consequences of Europe's disunity stand in sharp contrast to those of China's unity. From time to time the Chinese court decided to halt other activities besides overseas navigation: it abandoned development of an elaborate water-driven spinning machine, stepped back from the verge of an industrial revolution in the 14th century, demolished or virtually abolished mechanical clocks after leading the world in clock construction, and retreated from mechanical devices and technology in general after the late 15th century. Those potentially harmful effects of unity have flared up again in modern China, notably during the madness of the Cultural Revolution in the 1960s and 1970s, when a decision by one or a few leaders closed the whole country's school systems for five years.

China's frequent unity and Europe's perpetual disunity both have a long history. The most productive areas of modern China were politically joined for the first time in 221 B.C. and have remained so for most of the time since then. China has had only a single writing system from the beginnings of literacy, a single dominant language for a long time, and substantial cultural unity for two thousand years. In contrast, Europe has never come remotely close to political unification: it was still splintered into 1,000 independent statelets in the 14th century, into 500 statelets in A.D. 1500, got down to a minimum of 25 states in the 1980s, and is now up again to nearly 40 at the moment that I write this sentence. Europe still has 45 languages, each with its own modified alphabet, and even greater cultural diversity. The disagreements that continue today to frustrate even modest attempts at European unification through the European Economic Community (EEC) are symptomatic of Europe's ingrained commitment to disunity.

Hence the real problem in understanding China's loss of political and technological preeminence to Europe is to understand China's chronic unity and Europe's chronic disunity. The answer is again suggested by maps (see page 415). Europe has a highly indented coastline, with five large peninsulas that approach islands in their isolation, and all of which evolved independent languages, ethnic groups, and governments: Greece, Italy, Iberia, Denmark, and Norway / Sweden. China's coastline is much smoother, and only the nearby Korean Peninsula attained separate importance. Europe has two islands (Britain and Ireland) sufficiently big to assert their political independence and to maintain their own languages and ethnicities, and one of them (Britain) big and close enough to become a major independent European power. But even China's two largest islands, Taiwan and Hainan, have each less than half the area of Ireland; neither was a major independent power until Taiwan's emergence in recent decades; and Japan's geographic isolation kept it until recently much more isolated politically from the Asian mainland than Britain has been from mainland Europe. Europe is carved up into independent linguistic, ethnic, and political units by high mountains (the Alps, Pyrenees, Carpathians, and Norwegian border mountains), while China's mountains east of the Tibetan plateau are much less formidable barriers. China's heartland is bound together from east to west by two long navigable river systems in rich alluvial valleys (the Yangtze and Yellow Rivers), and it is joined from north to south by relatively easy connections between these two river systems (eventually linked by canals). As a result, China very early became dominated by two huge geographic core areas of high productivity, themselves only weakly separated from each other and eventually fused into a single core. Europe's two biggest rivers, the Rhine and Danube, are smaller and connect much less of Europe. Unlike China, Europe has many scattered small core areas, none big enough to dominate the others for long, and each the center of chronically independent states.

Once China was finally unified, in 221 B.C., no other independent state ever had a chance of arising and persisting for long in China. Although periods of disunity returned several times after 221 B.C., they always ended in reunification. But the unification of Europe has resisted the efforts of such determined conquerors as Charlemagne, Napoleon, and Hitler; even the Roman Empire at its peak never controlled more than half of Europe's area.

Thus, geographic connectedness and only modest internal barriers gave China an initial advantage. North China, South China, the coast, and the



Comparison of the coastlines of China and of Europe, drawn to the same scale. Note that Europe's is much more indented and includes more large peninsulas and two large islands.

interior contributed different crops, livestock, technologies, and cultural features to the eventually unified China. For example, millet cultivation, bronze technology, and writing arose in North China, while rice cultivation and cast-iron technology emerged in South China. For much of this book I have emphasized the diffusion of technology that takes place in the absence of formidable barriers. But China's connectedness eventually became a disadvantage, because a decision by one despot could and repeatedly did halt innovation. In contrast, Europe's geographic balkanization resulted in dozens or hundreds of independent, competing statelets and centers of innovation. If one state did not pursue some particular innovation, another did, forcing neighboring states to do likewise or else be conquered or left economically behind. Europe's barriers were sufficient to prevent political unification, but insufficient to halt the spread of technology and ideas. There has never been one despot who could turn off the tap for all of Europe, as of China.

These comparisons suggest that geographic connectedness has exerted both positive and negative effects on the evolution of technology. As a result, in the very long run, technology may have developed most rapidly in regions with moderate connectedness, neither too high nor too low. Technology's course over the last 1,000 years in China, Europe, and possibly the Indian subcontinent exemplifies those net effects of high, moderate, and low connectedness, respectively.

Naturally, additional factors contributed to history's diverse courses in different parts of Eurasia. For instance, the Fertile Crescent, China, and Europe differed in their exposure to the perennial threat of barbarian invasions by horse-mounted pastoral nomads of Central Asia. One of those nomad groups (the Mongols) eventually destroyed the ancient irrigation systems of Iran and Iraq, but none of the Asian nomads ever succeeded in establishing themselves in the forests of western Europe beyond the Hungarian plains. Environmental factors also include the Fertile Crescent's geographically intermediate location, controlling the trade routes linking China and India to Europe, and China's more remote location from Eurasia's other advanced civilizations, making China a gigantic virtual island within a continent. China's relative isolation is especially relevant to its adoption and then rejection of technologies, so reminiscent of the rejections on Tasmania and other islands (Chapters 13 and 15). But this brief discussion may at least indicate the relevance of environmental factors to smaller-scale and shorter-term patterns of history, as well as to history's broadest pattern.

The histories of the Fertile Crescent and China also hold a salutary lesson for the modern world: circumstances change, and past primacy is no guarantee of future primacy. One might even wonder whether the geographical reasoning employed throughout this book has at last become wholly irrelevant in the modern world, now that ideas diffuse everywhere instantly on the Internet and cargo is routinely airfreighted overnight between continents. It might seem that entirely new rules apply to competition between the world's peoples, and that as a result new powers are emerging—such as Taiwan, Korea, Malaysia, and especially Japan.

On reflection, though, we see that the supposedly new rules are just variations on the old ones. Yes, the transistor, invented at Bell Labs in the eastern United States in 1947, leapt 8,000 miles to launch an electronics industry in Japan—but it did not make the shorter leap to found new industries in Zaire or Paraguay. The nations rising to new power are still ones that were incorporated thousands of years ago into the old centers of dominance based on food production, or that have been repopulated by peoples from those centers. Unlike Zaire or Paraguay, Japan and the other new powers were able to exploit the transistor quickly because their populations already had a long history of literacy, metal machinery, and centralized government. The world's two earliest centers of food production, the Fertile Crescent and China, still dominate the modern world, either through their immediate successor states (modern China), or through states situated in neighboring regions influenced early by those two centers (Japan, Korea, Malaysia, and Europe), or through states repopulated or ruled by their overseas emigrants (the United States, Australia, Brazil). Prospects for world dominance of sub-Saharan Africans, Aboriginal Australians, and Native Americans remain dim. The hand of history's course at 8000 B.C. lies heavily on us.

AMONG OTHER FACTORS relevant to answering Yali's question, cultural factors and influences of individual people loom large. To take the former first, human cultural traits vary greatly around the world. Some of that cultural variation is no doubt a product of environmental variation, and I have discussed many examples in this book. But an important question concerns the possible significance of local cultural factors unrelated to the environment. A minor cultural feature may arise for trivial, temporary local reasons, become fixed, and then predispose a society toward more important cultural choices, as is suggested by applications of chaos theory to other fields of science. Such cultural processes are among history's wild cards that would tend to make history unpredictable.

As one example, I mentioned in Chapter 13 the QWERTY keyboard for typewriters. It was adopted initially, out of many competing keyboard designs, for trivial specific reasons involving early typewriter construction in America in the 1860s, typewriter salesmanship, a decision in 1882 by a certain Ms. Longley who founded the Shorthand and Typewriter Institute in Cincinnati, and the success of Ms. Longley's star typing pupil Frank McGurrin, who thrashed Ms. Longley's non-QWERTY competitor Louis Taub in a widely publicized typing contest in 1888. The decision could have gone to another keyboard at any of numerous stages between the 1860s and the 1880s; nothing about the American environment favored the QWERTY keyboard over its rivals. Once the decision had been made, though, the QWERTY keyboard became so entrenched that it was also adopted for computer keyboard design a century later. Equally trivial specific reasons, now lost in the remote past, may have lain behind the Sumerian adoption of a counting system based on 12 instead of 10 (leading to our modern 60-minute hour, 24-hour day, 12-month year, and 360-degree circle), in contrast to the widespread Mesoamerican counting system based on 20 (leading to its calendar using two concurrent cycles of 260 named days and a 365-day year).

Those details of typewriter, clock, and calendar design have not affected the competitive success of the societies adopting them. But it is easy to imagine how they could have. For example, if the QWERTY keyboard of the United States had not been adopted elsewhere in the world as well—say, if Japan or Europe had adopted the much more efficient Dvorak keyboard—that trivial decision in the 19th century might have had big consequences for the competitive position of 20th-century American technology.

Similarly, a study of Chinese children suggested that they learn to write more quickly when taught an alphabetic transcription of Chinese sounds (termed pinyin) than when taught traditional Chinese writing, with its thousands of signs. It has been suggested that the latter arose because of their convenience for distinguishing the large numbers of Chinese words possessing differing meanings but the same sounds (homophones). If so, the abundance of homophones in the Chinese language may have had a large impact on the role of literacy in Chinese society, yet it seems unlikely that there was anything in the Chinese environment selecting for a language rich in homophones. Did a linguistic or cultural factor account for the otherwise puzzling failure of complex Andean civilizations to develop writing? Was there anything about India's environment predisposing toward rigid socioeconomic castes, with grave consequences for the development of technology in India? Was there anything about the Chinese environment predisposing toward Confucian philosophy and cultural conservatism, which may also have profoundly affected history? Why was proselytizing religion (Christianity and Islam) a driving force for colonization and conquest among Europeans and West Asians but not among Chinese?

These examples illustrate the broad range of questions concerning cultural idiosyncrasies, unrelated to environment and initially of little significance, that might evolve into influential and long-lasting cultural features. Their significance constitutes an important unanswered question. It can best be approached by concentrating attention on historical patterns that remain puzzling after the effects of major environmental factors have been taken into account.

WHAT ABOUT THE effects of idiosyncratic individual people? A familiar modern example is the narrow failure, on July 20, 1944, of the assassination attempt against Hitler and of a simultaneous uprising in Berlin. Both had been planned by Germans who were convinced that the war could not be won and who wanted to seek peace then, at a time when the eastern front between the German and Russian armies still lay mostly within Russia's borders. Hitler was wounded by a time bomb in a briefcase placed under a conference table; he might have been killed if the case had been placed slightly closer to the chair where he was sitting. It is likely that the modern map of Eastern Europe and the Cold War's course would have been significantly different if Hitler had indeed been killed and if World War II had ended then.

Less well known but even more fateful was a traffic accident in the summer of 1930, over two years before Hitler's seizure of power in Germany, when a car in which he was riding in the "death seat" (right front passenger seat) collided with a heavy trailer truck. The truck braked just in time to avoid running over Hitler's car and crushing him. Because of the degree to which Hitler's psychopathology determined Nazi policy and success, the form of an eventual World War II would probably have been quite different if the truck driver had braked one second later.

One can think of other individuals whose idiosyncrasies apparently influenced history as did Hitler's: Alexander the Great, Augustus, Buddha, Christ, Lenin, Martin Luther, the Inca emperor Pachacuti, Mohammed, William the Conqueror, and the Zulu king Shaka, to name a few. To what extent did each really change events, as opposed to "just" happening to be the right person in the right place at the right time? At the one extreme is the view of the historian Thomas Carlyle: "Universal history, the history of what man *[sic]* has accomplished in this world, is at bottom the History of the Great Men who have worked here." At the opposite extreme is the view of the Prussian statesman Otto von Bismarck, who unlike Carlyle had long firsthand experience of politics' inner workings: "The statesman's task is to hear God's footsteps marching through history, and to try to catch on to His coattails as He marches past."

Like cultural idiosyncrasies, individual idiosyncrasies throw wild cards into the course of history. They may make history inexplicable in terms of environmental forces, or indeed of any generalizable causes. For the purposes of this book, however, they are scarcely relevant, because even the most ardent proponent of the Great Man theory would find it difficult to interpret history's broadest pattern in terms of a few Great Men. Perhaps Alexander the Great did nudge the course of western Eurasia's already literate, food-producing, iron-equipped states, but he had nothing to do with the fact that western Eurasia already supported literate, food-producing, iron-equipped states at a time when Australia still supported only nonliterate hunter-gatherer tribes lacking metal tools. Nevertheless, it remains an open question how wide and lasting the effects of idiosyncratic individuals on history really are.

THE DISCIPLINE OF history is generally not considered to be a science, but something closer to the humanities. At best, history is classified among the social sciences, of which it rates as the least scientific. While the field of government is often termed "political science" and the Nobel Prize in economics refers to "economic science," history departments rarely if ever label themselves "Department of Historical Science." Most historians do not think of themselves as scientists and receive little training in acknowledged sciences and their methodologies. The sense that history is nothing more than a mass of details is captured in numerous aphorisms: "History is just one damn fact after another," "History is more or less bunk," "There is no law of history any more than of a kaleidoscope," and so on.

One cannot deny that it is more difficult to extract general principles from studying history than from studying planetary orbits. However, the difficulties seem to me not fatal. Similar ones apply to other historical subjects whose place among the natural sciences is nevertheless secure, including astronomy, climatology, ecology, evolutionary biology, geology, and paleontology. People's image of science is unfortunately often based on physics and a few other fields with similar methodologies. Scientists in those fields tend to be ignorantly disdainful of fields to which those methodologies are inappropriate and which must therefore seek other methodologies—such as my own research areas of ecology and evolutionary biology. But recall that the word "science" means "knowledge" (from the Latin *scire,* "to know," and *scientia,* "knowledge"), to be obtained by whatever methods are most appropriate to the particular field. Hence I have much empathy with students of human history for the difficulties they face.

Historical sciences in the broad sense (including astronomy and the like) share many features that set them apart from nonhistorical sciences such as physics, chemistry, and molecular biology. I would single out four: methodology, causation, prediction, and complexity.

In physics the chief method for gaining knowledge is the laboratory experiment, by which one manipulates the parameter whose effect is in question, executes parallel control experiments with that parameter held constant, holds other parameters constant throughout, replicates both the experimental manipulation and the control experiment, and obtains quantitative data. This strategy, which also works well in chemistry and molecular biology, is so identified with science in the minds of many people that experimentation is often held to be the essence of the scientific method. But laboratory experimentation can obviously play little or no role in many of the historical sciences. One cannot interrupt galaxy formation, start and stop hurricanes and ice ages, experimentally exterminate grizzly bears in a few national parks, or rerun the course of dinosaur evolution. Instead, one must gain knowledge in these historical sciences by other means, such as observation, comparison, and so-called natural experiments (to which I shall return in a moment).

Historical sciences are concerned with chains of proximate and ultimate causes. In most of physics and chemistry the concepts of "ultimate cause," "purpose," and "function" are meaningless, yet they are essential to understanding living systems in general and human activities in particular. For instance, an evolutionary biologist studying Arctic hares whose fur color turns from brown in summer to white in winter is not satisfied with identifying the mundane proximate causes of fur color in terms of the fur pigments' molecular structures and biosynthetic pathways. The more important questions involve function (camouflage against predators?) and ultimate cause (natural selection starting with an ancestral hare population with seasonally unchanging fur color?). Similarly, a European historian is not satisfied with describing the condition of Europe in both 1815 and 1918 as having just achieved peace after a costly pan-European war. Understanding the contrasting chains of events leading up to the two peace treaties is essential to understanding why an even more costly pan-European war broke out again within a few decades of 1918 but not of 1815. But chemists do not assign a purpose or function to a collision of two gas molecules, nor do they seek an ultimate cause for the collision.

Still another difference between historical and nonhistorical sciences involves prediction. In chemistry and physics the acid test of one's understanding of a system is whether one can successfully predict its future behavior. Again, physicists tend to look down on evolutionary biology and history, because those fields appear to fail this test. In historical sciences, one can provide a posteriori explanations (e.g., why an asteroid impact on Earth 66 million years ago may have driven dinosaurs but not many other species to extinction), but a priori predictions are more difficult (we would be uncertain which species would be driven to extinction if we did not have the actual past event to guide us). However, historians and historical scientists do make and test predictions about what future discoveries of data will show us about past events.

The properties of historical systems that complicate attempts at prediction can be described in several alternative ways. One can point out that human societies and dinosaurs are extremely complex, being characterized by an enormous number of independent variables that feed back on each other. As a result, small changes at a lower level of organization can lead to emergent changes at a higher level. A typical example is the effect of that one truck driver's braking response, in Hitler's nearly fatal traffic accident of 1930, on the lives of a hundred million people who were killed or wounded in World War II. Although most biologists agree that biological systems are in the end wholly determined by their physical properties and obey the laws of quantum mechanics, the systems' complexity means, for practical purposes, that that deterministic causation does not translate into predictability. Knowledge of quantum mechanics does not help one understand why introduced placental predators have exterminated so many Australian marsupial species, or why the Allied Powers rather than the Central Powers won World War I.

Each glacier, nebula, hurricane, human society, and biological species, and even each individual and cell of a sexually reproducing species, is unique, because it is influenced by so many variables and made up of so many variable parts. In contrast, for any of the physicist's elementary particles and isotopes and of the chemist's molecules, all individuals of the entity are identical to each other. Hence physicists and chemists can formulate universal deterministic laws at the macroscopic level, but biologists and historians can formulate only statistical trends. With a very high probability of being correct, I can predict that, of the next 1,000 babies born at the University of California Medical Center, where I work, not fewer than 480 or more than 520 will be boys. But I had no means of knowing in advance that my own two children would be boys. Similarly, historians note that tribal societies may have been more likely to develop into chiefdoms if the local population was sufficiently large and dense and if there was potential for surplus food production than if that was not the case. But each such local population has its own unique features, with the result that chiefdoms did emerge in the highlands of Mexico, Guatemala, Peru, and Madagascar, but not in those of New Guinea or Guadalcanal.

Still another way of describing the complexity and unpredictability of historical systems, despite their ultimate determinacy, is to note that long chains of causation may separate final effects from ultimate causes lying outside the domain of that field of science. For example, the dinosaurs may have been exterminated by the impact of an asteroid whose orbit was completely determined by the laws of classical mechanics. But if there had been any paleontologists living 67 million years ago, they could not have predicted the dinosaurs' imminent demise, because asteroids belong to a field of science otherwise remote from dinosaur biology. Similarly, the Little Ice Age of A.D. 1300-1500 contributed to the extinction of the Greenland Norse, but no historian, and probably not even a modern climatologist, could have predicted the Little Ice Age.

THUS, THE DIFFICULTIES historians face in establishing cause-and-effect relations in the history of human societies are broadly similar to the difficulties facing astronomers, climatologists, ecologists, evolutionary biologists, geologists, and paleontologists. To varying degrees, each of these fields is plagued by the impossibility of performing replicated, controlled experimental interventions, the complexity arising from enormous numbers of variables, the resulting uniqueness of each system, the consequent impossibility of formulating universal laws, and the difficulties of predicting emergent properties and future behavior. Prediction in history, as in other historical sciences, is most feasible on large spatial scales and over long times, when the unique features of millions of small-scale brief events become averaged out. Just as I could predict the sex ratio of the next 1,000 newborns but not the sexes of my own two children, the historian can recognize factors that made inevitable the broad outcome of the collision between American and Eurasian societies after 13,000 years of separate developments, but not the outcome of the 1960 U.S. presidential election. The details of which candidate said what during a single televised debate in October 1960 could have given the electoral victory to Nixon instead of to Kennedy, but no details of who said what could have blocked the European conquest of Native Americans.

How can students of human history profit from the experience of scientists in other historical sciences? A methodology that has proved useful involves the comparative method and so-called natural experiments. While neither astronomers studying galaxy formation nor human historians can manipulate their systems in controlled laboratory experiments, they both can take advantage of natural experiments, by comparing systems differing in the presence or absence (or in the strong or weak effect) of some putative causative factor. For example, epidemiologists, forbidden to feed large amounts of salt to people experimentally, have still been able to identify effects of high salt intake by comparing groups of humans who already differ greatly in their salt intake; and cultural anthropologists, unable to provide human groups experimentally with varying resource abundances for many centuries, still study long-term effects of resource abundance on human societies by comparing recent Polynesian populations living on islands differing naturally in resource abundance. The student of human history can draw on many more natural experiments than just comparisons among the five inhabited continents. Comparisons can also utilize large islands that have developed complex societies in a considerable degree of isolation (such as Japan, Madagascar, Native American Hispaniola, New Guinea, Hawaii, and many others), as well as societies on hundreds of smaller islands and regional societies within each of the continents.

Natural experiments in any field, whether in ecology or human history, are inherently open to potential methodological criticisms. Those include confounding effects of natural variation in additional variables besides the one of interest, as well as problems in inferring chains of causation from observed correlations between variables. Such methodological problems have been discussed in great detail for some of the historical sciences. In particular, epidemiology, the science of drawing inferences about human diseases by comparing groups of people (often by retrospective historical studies), has for a long time successfully employed formalized procedures for dealing with problems similar to those facing historians of human societies. Ecologists have also devoted much attention to the problems of natural experiments, a methodology to which they must resort in many cases where direct experimental interventions to manipulate relevant ecological variables would be immoral, illegal, or impossible. Evolutionary biologists have recently been developing ever more sophisticated methods for drawing conclusions from comparisons of different plants and animals of known evolutionary histories.

In short, I acknowledge that it is much more difficult to understand human history than to understand problems in fields of science where history is unimportant and where fewer individual variables operate. Nevertheless, successful methodologies for analyzing historical problems have been worked out in several fields. As a result, the histories of dinosaurs, nebulas, and glaciers are generally acknowledged to belong to fields of science rather than to the humanities. But introspection gives us far more insight into the ways of other humans than into those of dinosaurs. I am thus optimistic that historical studies of human societies can be pursued as scientifically as studies of dinosaurs—and with profit to our own society today, by teaching us what shaped the modern world, and what might shape our future.