

THE FATES OF HUMAN SOCIETIES

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WE ALL KNOW THAT HISTORY HAS PROCEEDED VERY DIFFERENTLY for peoples from different parts of the globe. In the 13,000 years since the end of the last Ice Age, some parts of the world developed literate industrial societies with metal tools, other parts developed only nonliterate farming societies, and still others retained societies of hunter-gatherers with stone tools. Those historical inequalities have cast long shadows on the modern world, because the literate societies with metal tools have conquered or exterminated the other societies. While those differences constitute the most basic fact of world history, the reasons for them remain uncertain and controversial. This puzzling-question of their origins was posed to me 25 years ago in a simple, personal form.

In July 1972 I was walking along a beach on the tropical island of New Guinea, where as a biologist I study bird evolution. I had already heard about a remarkable local politician named Yali, who was touring the district then. By chance, Yali and I were walking in the same direction on that day, and he overtook me. We walked together for an hour, talking during the whole time.

Yali radiated charisma and energy. His eyes flashed in a mesmerizing way. He talked confidently about himself, but he also asked lots of probing questions and listened intently. Our conversation began with a subject then

on every New Guinean's mind—the rapid pace of political developments. Papua New Guinea, as Yali's nation is now called, was at that time still administered by Australia as a mandate of the United Nations, but independence was in the air. Yali explained to me his role in getting local people to prepare for self-government.

After a while, Yali turned the conversation and began to quiz me. He had never been outside New Guinea and had not been educated beyond high school, but his curiosity was insatiable. First, he wanted to know about my work on New Guinea birds (including how much I got paid for it). I explained to him how different groups of birds had colonized New Guinea over the course of millions of years. He then asked how the ancestors of his own people had reached New Guinea over the last tens of thousands of years, and how white Europeans had colonized New Guinea within the last 200 years.

The conversation remained friendly, even though the tension between the two societies that Yali and I represented was familiar to both of us. Two centuries ago, all New Guineans were still “living in the Stone Age.” That is, they still used stone tools similar to those superseded in Europe by metal tools thousands of years ago, and they dwelt in villages not organized under any centralized political authority. Whites had arrived, imposed centralized government, and brought material goods whose value New Guineans instantly recognized, ranging from steel axes, matches, and medicines to clothing, soft drinks, and umbrellas. In New Guinea all these goods were referred to collectively as “cargo.”

Many of the white colonialists openly despised New Guineans as “primitive.” Even the least able of New Guinea's white “masters,” as they were still called in 1972, enjoyed a far higher standard of living than New Guineans, higher even than charismatic politicians like Yali. Yet Yali had quizzed lots of whites as he was then quizzing me, and I had quizzed lots of New Guineans. He and I both knew perfectly well that New Guineans are on the average at least as smart as Europeans. All those things must have been on Yali's mind when, with yet another penetrating glance of his flashing eyes, he asked me, “Why is it that you white people developed so much cargo and brought it to New Guinea, but we black people had little cargo of our own?”

It was a simple question that went to the heart of life as Yali experienced it. Yes, there still is a huge difference between the lifestyle of the average

New Guinean and that of the average European or American. Comparable differences separate the lifestyles of other peoples of the world as well. Those huge disparities must have potent causes that one might think would be obvious.

Yet Yali's apparently simple question is a difficult one to answer. I didn't have an answer then. Professional historians still disagree about the solution; most are no longer even asking the question. In the years since Yali and I had that conversation, I have studied and written about other aspects of human evolution, history, and language. This book, written twenty-five years later, attempts to answer Yali.

**ALTHOUGH YALI'S QUESTION** concerned only the contrasting lifestyles of New Guineans and of European whites, it can be extended to a larger set of contrasts within the modern world. Peoples of Eurasian origin, especially those still living in Europe and eastern Asia, plus those transplanted to North America, dominate the modern world in wealth and power. Other peoples, including most Africans, have thrown off European colonial domination but remain far behind in wealth and power. Still other peoples, such as the aboriginal inhabitants of Australia, the Americas, and southernmost Africa, are no longer even masters of their own lands but have been decimated, subjugated, and in some cases even exterminated by European colonialists.

Thus, questions about inequality in the modern world can be reformulated as follows. Why did wealth and power become distributed as they now are, rather than in some other way? For instance, why weren't Native Americans, Africans, and Aboriginal Australians the ones who decimated, subjugated, or exterminated Europeans and Asians?

We can easily push this question back one step. As of the year A.D. 1500, when Europe's worldwide colonial expansion was just beginning, peoples on different continents already differed greatly in technology and political organization. Much of Europe, Asia, and North Africa was the site of metal-equipped states or empires, some of them on the threshold of industrialization. Two Native American peoples, the Aztecs and the Incas, ruled over empires with stone tools. Parts of sub-Saharan Africa were divided among small states or chiefdoms with iron tools. Most other peoples—including all those of Australia and New Guinea, many Pacific

islands, much of the Americas, and small parts of sub-Saharan Africa—lived as farming tribes or even still as hunter-gatherer bands using stone tools.

Of course, those technological and political differences as of A.D. 1500 were the immediate cause of the modern world's inequalities. Empires with steel weapons were able to conquer or exterminate tribes with weapons of stone and wood. How, though, did the world get to be the way it was in A.D. 1500?

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.

**B**EFORE SEEKING ANSWERS to Yali's question, we should pause to consider some objections to discussing it at all. Some people take offense at the mere posing of the question, for several reasons.

One objection goes as follows. If we succeed in explaining how some people came to dominate other people, may this not seem to justify the domination? Doesn't it seem to say that the outcome was inevitable, and that it would therefore be futile to try to change the outcome today? This objection rests on a common tendency to confuse an explanation of causes with a justification or acceptance of results. What use one makes of a historical explanation is a question separate from the explanation itself. Understanding is more often used to try to alter an outcome than to repeat or perpetuate it. That's why psychologists try to understand the minds of murderers and rapists, why social historians try to understand genocide, and why physicians try to understand the causes of human disease. Those investigators do not seek to justify murder, rape, genocide, and illness. Instead, they seek to use their understanding of a chain of causes to interrupt the chain.

Second, doesn't addressing Yali's question automatically involve a Eurocentric approach to history, a glorification of western Europeans, and an obsession with the prominence of western Europe and Europeanized

America in the modern world? Isn't that prominence just an ephemeral phenomenon of the last few centuries, now fading behind the prominence of Japan and Southeast Asia? In fact, most of this book will deal with peoples other than Europeans. Rather than focus solely on interactions between Europeans and non-Europeans, we shall also examine interactions between different non-European peoples—especially those that took place within sub-Saharan Africa, Southeast Asia, Indonesia, and New Guinea, among peoples native to those areas. Far from glorifying peoples of western European origin, we shall see that most basic elements of their civilization were developed by other peoples living elsewhere and were then imported to western Europe.

Third, don't words such as "civilization," and phrases such as "rise of civilization," convey the false impression that civilization is good, tribal hunter-gatherers are miserable, and history for the past 13,000 years has involved progress toward greater human happiness? In fact, I do not assume that industrialized states are "better" than hunter-gatherer tribes, or that the abandonment of the hunter-gatherer lifestyle for iron-based statehood represents "progress," or that it has led to an increase in human happiness. My own impression, from having divided my life between United States cities and New Guinea villages, is that the so-called blessings of civilization are mixed. For example, compared with hunter-gatherers, citizens of modern industrialized states enjoy better medical care, lower risk of death by homicide, and a longer life span, but receive much less social support from friendships and extended families. My motive for investigating these geographic differences in human societies is not to celebrate one type of society over another but simply to understand what happened in history.

**D**OES YALI'S QUESTION really need another book to answer it? Don't we already know the answer? If so, what is it?

Probably the commonest explanation involves implicitly or explicitly assuming biological differences among peoples. In the centuries after A.D. 1500, as European explorers became aware of the wide differences among the world's peoples in technology and political organization, they assumed that those differences arose from differences in innate ability. With the rise of Darwinian theory, explanations were recast in terms of natural selection and of evolutionary descent. Technologically primitive peoples were con-

sidered evolutionary vestiges of human descent from apelike ancestors. The displacement of such peoples by colonists from industrialized societies exemplified the survival of the fittest. With the later rise of genetics, the explanations were recast once again, in genetic terms. Europeans became considered genetically more intelligent than Africans, and especially more so than Aboriginal Australians.

Today, segments of Western society publicly repudiate racism. Yet many (perhaps most!) Westerners continue to accept racist explanations privately or subconsciously. In Japan and many other countries, such explanations are still advanced publicly and without apology. Even educated white Americans, Europeans, and Australians, when the subject of Australian Aborigines comes up, assume that there is something primitive about the Aborigines themselves. They certainly look different from whites. Many of the living descendants of those Aborigines who survived the era of European colonization are now finding it difficult to succeed economically in white Australian society.

A seemingly compelling argument goes as follows. White immigrants to Australia built a literate, industrialized, politically centralized, democratic state based on metal tools and on food production, all within a century of colonizing a continent where the Aborigines had been living as tribal hunter-gatherers without metal for at least 40,000 years. Here were two successive experiments in human development, in which the environment was identical and the sole variable was the people occupying that environment. What further proof could be wanted to establish that the differences between Aboriginal Australian and European societies arose from differences between the peoples themselves?

The objection to such racist explanations is not just that they are loathsome, but also that they are wrong. Sound evidence for the existence of human differences in intelligence that parallel human differences in technology is lacking. In fact, as I shall explain in a moment, modern "Stone Age" peoples are on the average probably more intelligent, not less intelligent, than industrialized peoples. Paradoxical as it may sound, we shall see in Chapter 15 that white immigrants to Australia do not deserve the credit usually accorded to them for building a literate industrialized society with the other virtues mentioned above. In addition, peoples who until recently were technologically primitive—such as Aboriginal Australians and New Guineans—routinely master industrial technologies when given opportunities to do so.

An enormous effort by cognitive psychologists has gone into the search for differences in IQ between peoples of different geographic origins now living in the same country. In particular, numerous white American psychologists have been trying for decades to demonstrate that black Americans of African origins are innately less intelligent than white Americans of European origins. However, as is well known, the peoples compared differ greatly in their social environment and educational opportunities. This fact creates double difficulties for efforts to test the hypothesis that intellectual differences underlie technological differences. First, even our cognitive abilities as adults are heavily influenced by the social environment that we experienced during childhood, making it hard to discern any influence of preexisting genetic differences. Second, tests of cognitive ability (like IQ tests) tend to measure cultural learning and not pure innate intelligence, whatever that is. Because of those undoubted effects of childhood environment and learned knowledge on IQ test results, the psychologists' efforts to date have not succeeded in convincingly establishing the postulated genetic deficiency in IQs of nonwhite peoples.

My perspective on this controversy comes from 33 years of working with New Guineans in their own intact societies. From the very beginning of my work with New Guineans, they impressed me as being on the average more intelligent, more alert, more expressive, and more interested in things and people around them than the average European or American is. At some tasks that one might reasonably suppose to reflect aspects of brain function, such as the ability to form a mental map of unfamiliar surroundings, they appear considerably more adept than Westerners. Of course, New Guineans tend to perform poorly at tasks that Westerners have been trained to perform since childhood and that New Guineans have not. Hence when unschooled New Guineans from remote villages visit towns, they look stupid to Westerners. Conversely, I am constantly aware of how stupid I look to New Guineans when I'm with them in the jungle, displaying my incompetence at simple tasks (such as following a jungle trail or erecting a shelter) at which New Guineans have been trained since childhood and I have not.

It's easy to recognize two reasons why my impression that New Guineans are smarter than Westerners may be correct. First, Europeans have for thousands of years been living in densely populated societies with central governments, police, and judiciaries. In those societies, infectious epidemic diseases of dense populations (such as smallpox) were historically the

major cause of death, while murders were relatively uncommon and a state of war was the exception rather than the rule. Most Europeans who escaped fatal infections also escaped other potential causes of death and proceeded to pass on their genes. Today, most live-born Western infants survive fatal infections as well and reproduce themselves, regardless of their intelligence and the genes they bear. In contrast, New Guineans have been living in societies where human numbers were too low for epidemic diseases of dense populations to evolve. Instead, traditional New Guineans suffered high mortality from murder, chronic tribal warfare, accidents, and problems in procuring food.

Intelligent people are likelier than less intelligent ones to escape those causes of high mortality in traditional New Guinea societies. However, the differential mortality from epidemic diseases in traditional European societies had little to do with intelligence, and instead involved genetic resistance dependent on details of body chemistry. For example, people with blood group B or O have a greater resistance to smallpox than do people with blood group A. That is, natural selection promoting genes for intelligence has probably been far more ruthless in New Guinea than in more densely populated, politically complex societies, where natural selection for body chemistry was instead more potent.

Besides this genetic reason, there is also a second reason why New Guineans may have come to be smarter than Westerners. Modern European and American children spend much of their time being passively entertained by television, radio, and movies. In the average American household, the TV set is on for seven hours per day. In contrast, traditional New Guinea children have virtually no such opportunities for passive entertainment and instead spend almost all of their waking hours actively doing something, such as talking or playing with other children or adults. Almost all studies of child development emphasize the role of childhood stimulation and activity in promoting mental development, and stress the irreversible mental stunting associated with reduced childhood stimulation. This effect surely contributes a non-genetic component to the superior average mental function displayed by New Guineans.

That is, in mental ability New Guineans are probably genetically superior to Westerners, and they surely are superior in escaping the devastating developmental disadvantages under which most children in industrialized societies now grow up. Certainly, there is no hint at all of any intellectual disadvantage of New Guineans that could serve to answer Yali's question.

The same two genetic and childhood developmental factors are likely to distinguish not only New Guineans from Westerners, but also hunter-gatherers and other members of technologically primitive societies from members of technologically advanced societies in general. Thus, the usual racist assumption has to be turned on its head. Why is it that Europeans, despite their likely genetic disadvantage and (in modern times) their undoubted developmental disadvantage, ended up with much more of the cargo? Why did New Guineans wind up technologically primitive, despite what I believe to be their superior intelligence?

A GENETIC EXPLANATION isn't the only possible answer to Yali's question. Another one, popular with inhabitants of northern Europe, invokes the supposed stimulatory effects of their homeland's cold climate and the inhibitory effects of hot, humid, tropical climates on human creativity and energy. Perhaps the seasonally variable climate at high latitudes poses more diverse challenges than does a seasonally constant tropical climate. Perhaps cold climates require one to be more technologically inventive to survive, because one must build a warm home and make warm clothing, whereas one can survive in the tropics with simpler housing and no clothing. Or the argument can be reversed to reach the same conclusion: the long winters at high latitudes leave people with much time in which to sit indoors and invent.

Although formerly popular, this type of explanation, too, fails to survive scrutiny. As we shall see, the peoples of northern Europe contributed nothing of fundamental importance to Eurasian civilization until the last thousand years; they simply had the good luck to live at a geographic location where they were likely to receive advances (such as agriculture, wheels, writing, and metallurgy) developed in warmer parts of Eurasia. In the New World the cold regions at high latitude were even more of a human backwater. The sole Native American societies to develop writing arose in Mexico south of the Tropic of Cancer; the oldest New World pottery comes from near the equator in tropical South America; and the New World society generally considered the most advanced in art, astronomy, and other respects was the Classic Maya society of the tropical Yucatán and Guatemala in the first millennium A.D.

Still a third type of answer to Yali invokes the supposed importance of lowland river valleys in dry climates, where highly productive agriculture

depended on large-scale irrigation systems that in turn required centralized bureaucracies. This explanation was suggested by the undoubted fact that the earliest known empires and writing systems arose in the Tigris and Euphrates Valleys of the Fertile Crescent and in the Nile Valley of Egypt. Water control systems also appear to have been associated with centralized political organization in some other areas of the world, including the Indus Valley of the Indian subcontinent, the Yellow and Yangtze Valleys of China, the Maya lowlands of Mesoamerica, and the coastal desert of Peru.

However, detailed archaeological studies have shown that complex irrigation systems did not *accompany* the rise of centralized bureaucracies but *followed* after a considerable lag. That is, political centralization arose for some other reason and then permitted construction of complex irrigation systems. None of the crucial developments preceding political centralization in those same parts of the world were associated with river valleys or with complex irrigation systems. For example, in the Fertile Crescent food production and village life originated in hills and mountains, not in lowland river valleys. The Nile Valley remained a cultural backwater for about 3,000 years after village food production began to flourish in the hills of the Fertile Crescent. River valleys of the southwestern United States eventually came to support irrigation agriculture and complex societies, but only after many of the developments on which those societies rested had been imported from Mexico. The river valleys of southeastern Australia remained occupied by tribal societies without agriculture.

Yet another type of explanation lists the immediate factors that enabled Europeans to kill or conquer other peoples—especially European guns, infectious diseases, steel tools, and manufactured products. Such an explanation is on the right track, as those factors demonstrably *were* directly responsible for European conquests. However, this hypothesis is incomplete, because it still offers only a proximate (first-stage) explanation identifying immediate causes. It invites a search for ultimate causes: why were Europeans, rather than Africans or Native Americans, the ones to end up with guns, the nastiest germs, and steel?

While some progress has been made in identifying those ultimate causes in the case of Europe's conquest of the New World, Africa remains a big puzzle. Africa is the continent where protohumans evolved for the longest time, where anatomically modern humans may also have arisen, and where native diseases like malaria and yellow fever killed European explorers. If a long head start counts for anything, why didn't guns and

steel arise first in Africa, permitting Africans and their germs to conquer Europe? And what accounts for the failure of Aboriginal Australians to pass beyond the stage of hunter-gatherers with stone tools?

Questions that emerge from worldwide comparisons of human societies formerly attracted much attention from historians and geographers. The best-known modern example of such an effort was Arnold Toynbee's 12-volume *Study of History*. Toynbee was especially interested in the internal dynamics of 23 advanced civilizations, of which 22 were literate and 19 were Eurasian. He was less interested in prehistory and in simpler, nonliterate societies. Yet the roots of inequality in the modern world lie far back in prehistory. Hence Toynbee did not pose Yali's question, nor did he come to grips with what I see as history's broadest pattern. Other available books on world history similarly tend to focus on advanced literate Eurasian civilizations of the last 5,000 years; they have a very brief treatment of pre-Columbian Native American civilizations, and an even briefer discussion of the rest of the world except for its recent interactions with Eurasian civilizations. Since Toynbee's attempt, worldwide syntheses of historical causation have fallen into disfavor among most historians, as posing an apparently intractable problem.

Specialists from several disciplines have provided global syntheses of their subjects. Especially useful contributions have been made by ecological geographers, cultural anthropologists, biologists studying plant and animal domestication, and scholars concerned with the impact of infectious diseases on history. These studies have called attention to parts of the puzzle, but they provide only pieces of the needed broad synthesis that has been missing.

Thus, there is no generally accepted answer to Yali's question. On the one hand, the proximate explanations are clear: some peoples developed guns, germs, steel, and other factors conferring political and economic power before others did; and some peoples never developed these power factors at all. On the other hand, the ultimate explanations—for example, why bronze tools appeared early in parts of Eurasia, late and only locally in the New World, and never in Aboriginal Australia—remain unclear.

Our present lack of such ultimate explanations leaves a big intellectual gap, since the broadest pattern of history thus remains unexplained. Much more serious, though, is the moral gap left unfilled. It is perfectly obvious to everyone, whether an overt racist or not, that different peoples have fared differently in history. The modern United States is a European-

molded society, occupying lands conquered from Native Americans and incorporating the descendants of millions of sub-Saharan black Africans brought to America as slaves. Modern Europe is not a society molded by sub-Saharan black Africans who brought millions of Native Americans as slaves.

These results are completely lopsided: it was not the case that 51 percent of the Americas, Australia, and Africa was conquered by Europeans, while 49 percent of Europe was conquered by Native Americans, Aboriginal Australians, or Africans. The whole modern world has been shaped by lopsided outcomes. Hence they must have inexorable explanations, ones more basic than mere details concerning who happened to win some battle or develop some invention on one occasion a few thousand years ago.

It *seems* logical to suppose that history's pattern reflects innate differences among people themselves. Of course, we're taught that it's not polite to say so in public. We read of technical studies claiming to demonstrate inborn differences, and we also read rebuttals claiming that those studies suffer from technical flaws. We see in our daily lives that some of the conquered peoples continue to form an underclass, centuries after the conquests or slave imports took place. We're told that this too is to be attributed not to any biological shortcomings but to social disadvantages and limited opportunities.

Nevertheless, we have to wonder. We keep seeing all those glaring, persistent differences in peoples' status. We're assured that the seemingly transparent biological explanation for the world's inequalities as of A.D. 1500 is wrong, but we're not told what the correct explanation is. Until we have some convincing, detailed, agreed-upon explanation for the broad pattern of history, most people will continue to suspect that the racist biological explanation is correct after all. That seems to me the strongest argument for writing this book.

**A**UTHORS ARE REGULARLY asked by journalists to summarize a long book in one sentence. For this book, here is such a sentence: "History followed different courses for different peoples because of differences among peoples' environments, not because of biological differences among peoples themselves."

Naturally, the notion that environmental geography and biogeography influenced societal development is an old idea. Nowadays, though, the

most difficult fruit trees to cultivate and among the last major ones to be domesticated in Eurasia, because their propagation requires the difficult technique of grafting. There is no evidence for large-scale cultivation of apples even in the Fertile Crescent and in Europe until classical Greek times, 8,000 years after the rise of Eurasian food production began. If Native Americans had proceeded at the same rate in inventing or acquiring grafting techniques, they too would eventually have domesticated apples—around the year A.D. 5500, some 8,000 years after the rise of domestication in North America around 2500 B.C.

Thus, the reason for the failure of Native Americans to domesticate North American apples by the time Europeans arrived lay neither with the people nor with the apples. As far as biological prerequisites for apple domestication were concerned, North American Indian farmers were like Eurasian farmers, and North American wild apples were like Eurasian wild apples. Indeed, some of the supermarket apple varieties now being munching by readers of this chapter have been developed recently by crossing Eurasian apples with wild North American apples. Instead, the reason Native Americans did not domesticate apples lay with the entire suite of wild plant and animal species available to Native Americans. That suite's modest potential for domestication was responsible for the late start of food production in North America.

## CHAPTER 9

# ZEBRAS, UNHAPPY MARRIAGES, AND THE ANNA KARENINA PRINCIPLE

DOMESTICABLE ANIMALS ARE ALL ALIKE; EVERY UNDOMESTICABLE animal is undomesticable in its own way.

If you think you've already read something like that before, you're right. Just make a few changes, and you have the famous first sentence of Tolstoy's great novel *Anna Karenina*: "Happy families are all alike; every unhappy family is unhappy in its own way." By that sentence, Tolstoy meant that, in order to be happy, a marriage must succeed in many different respects: sexual attraction, agreement about money, child discipline, religion, in-laws, and other vital issues. Failure in any one of those essential respects can doom a marriage even if it has all the other ingredients needed for happiness.

This principle can be extended to understanding much else about life besides marriage. We tend to seek easy, single-factor explanations of success. For most important things, though, success actually requires avoiding many separate possible causes of failure. The *Anna Karenina* principle explains a feature of animal domestication that had heavy consequences for human history—namely, that so many seemingly suitable big wild mammal species, such as zebras and peccaries, have never been domesticated and that the successful domesticates were almost exclusively Eurasian. Having in the preceding two chapters discussed why so many wild

plant species seemingly suitable for domestication were never domesticated, we shall now tackle the corresponding question for domestic mammals. Our former question about apples or Indians becomes a question of zebras or Africans.

**I**N CHAPTER 4 we reminded ourselves of the many ways in which big domestic mammals were crucial to those human societies possessing them. Most notably, they provided meat, milk products, fertilizer, land transport, leather, military assault vehicles, plow traction, and wool, as well as germs that killed previously unexposed peoples.

In addition, of course, small domestic mammals and domestic birds and insects have also been useful to humans. Many birds were domesticated for meat, eggs, and feathers: the chicken in China, various duck and goose species in parts of Eurasia, turkeys in Mesoamerica, guinea fowl in Africa, and the Muscovy duck in South America. Wolves were domesticated in Eurasia and North America to become our dogs used as hunting companions, sentinels, pets, and, in some societies, food. Rodents and other small mammals domesticated for food included the rabbit in Europe, the guinea pig in the Andes, a giant rat in West Africa, and possibly a rodent called the hutia on Caribbean islands. Ferrets were domesticated in Europe to hunt rabbits, and cats were domesticated in North Africa and Southwest Asia to hunt rodent pests. Small mammals domesticated as recently as the 19th and 20th centuries include foxes, mink, and chinchillas grown for fur and hamsters kept as pets. Even some insects have been domesticated, notably Eurasia's honeybee and China's silkworm moth, kept for honey and silk, respectively.

Many of these small animals thus yielded food, clothing, or warmth. But none of them pulled plows or wagons, none bore riders, none except dogs pulled sleds or became war machines, and none of them have been as important for food as have big domestic mammals. Hence the rest of this chapter will confine itself to the big mammals.

**T**HE IMPORTANCE OF domesticated mammals rests on surprisingly few species of big terrestrial herbivores. (Only terrestrial mammals have been domesticated, for the obvious reason that aquatic mammals were difficult to maintain and breed until the development of modern Sea World facilities.)

ties.) If one defines "big" as "weighing over 100 pounds," then only 14 such species were domesticated before the twentieth century (see Table 9.1 for a list). Of those Ancient Fourteen, 9 (the "Minor Nine" of Table 9.1) became important livestock for people in only limited areas of the globe: the Arabian camel, Bactrian camel, llama / alpaca (distinct breeds of the same ancestral species), donkey, reindeer, water buffalo, yak, banteng, and gaur. Only 5 species became widespread and important around the world. Those Major Five of mammal domestication are the cow, sheep, goat, pig, and horse.

This list may at first seem to have glaring omissions. What about the African elephants with which Hannibal's armies crossed the Alps? What about the Asian elephants still used as work animals in Southeast Asia today? No, I didn't forget them, and that raises an important distinction. Elephants have been tamed, but never domesticated. Hannibal's elephants were, and Asian work elephants are, just wild elephants that were captured and tamed; they were not bred in captivity. In contrast, a domesticated animal is defined as an animal selectively bred in captivity and thereby modified from its wild ancestors, for use by humans who control the animal's breeding and food supply.

That is, domestication involves wild animals' being transformed into something more useful to humans. Truly domesticated animals differ in various ways from their wild ancestors. These differences result from two processes: human selection of those individual animals more useful to humans than other individuals of the same species, and automatic evolutionary responses of animals to the altered forces of natural selection operating in human environments as compared with wild environments. We already saw in Chapter 7 that all of these statements also apply to plant domestication.

The ways in which domesticated animals have diverged from their wild ancestors include the following. Many species changed in size: cows, pigs, and sheep became smaller under domestication, while guinea pigs became larger. Sheep and alpacas were selected for retention of wool and reduction or loss of hair, while cows have been selected for high milk yields. Several species of domestic animals have smaller brains and less developed sense organs than their wild ancestors, because they no longer need the bigger brains and more developed sense organs on which their ancestors depended to escape from wild predators.

To appreciate the changes that developed under domestication, just

TABLE 9.1 The Ancient Fourteen Species of Big Herbivorous Domestic Mammals

| The Major Five                                                                                                                                                                                                                                                        |  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|
| 1. <i>Sheep</i> . Wild ancestor: the Asiatic mouflon sheep of West and Central Asia. Now worldwide.                                                                                                                                                                   |  |
| 2. <i>Goat</i> . Wild ancestor: the bezoar goat of West Asia. Now worldwide.                                                                                                                                                                                          |  |
| 3. <i>Cow, alias ox or cattle</i> . Wild ancestor: the now extinct aurochs, formerly distributed over Eurasia and North Africa. Now worldwide.                                                                                                                        |  |
| 4. <i>Pig</i> . Wild ancestor: the wild boar, distributed over Eurasia and North Africa. Now worldwide. Actually an omnivore (regularly eats both animal and plant food), whereas the other 13 of the Ancient Fourteen are more strictly herbivores.                  |  |
| 5. <i>Horse</i> . Wild ancestor: now extinct wild horses of southern Russia; a different subspecies of the same species survived in the wild to modern times as Przewalski's horse of Mongolia. Now worldwide.                                                        |  |
| The Minor Nine                                                                                                                                                                                                                                                        |  |
| 6. <i>Arabian (one-humped) camel</i> . Wild ancestor: now extinct, formerly lived in Arabia and adjacent areas. Still largely restricted to Arabia and northern Africa, though feral in Australia.                                                                    |  |
| 7. <i>Bactrian (two-humped) camel</i> . Wild ancestor: now extinct, lived in Central Asia. Still largely confined to Central Asia.                                                                                                                                    |  |
| 8. <i>Llama and alpaca</i> . These appear to be well-differentiated breeds of the same species, rather than different species. Wild ancestor: the guanaco of the Andes. Still largely confined to the Andes, although some are bred as pack animals in North America. |  |
| 9. <i>Donkey</i> . Wild ancestor: the African wild ass of North Africa and formerly perhaps the adjacent area of Southwest Asia. Originally confined as a domestic animal to North Africa and western Eurasia, more recently also used elsewhere.                     |  |
| 10. <i>Reindeer</i> . Wild ancestor: the reindeer of northern Eurasia. Still largely confined as a domestic animal to that area, though now some are also used in Alaska.                                                                                             |  |
| 11. <i>Water buffalo</i> . Wild ancestor lives in Southeast Asia. Still used as a domestic animal mainly in that area, though many are also used in Brazil and others have escaped to the wild in Australia and other places.                                         |  |

12. *Yak*. Wild ancestor: the wild yak of the Himalayas and Tibetan plateau. Still confined as a domestic animal to that area.
13. *Bali cattle*. Wild ancestor: the banteng (a relative of the aurochs) of Southeast Asia. Still confined as a domestic animal to that area.
14. *Mithan*. Wild ancestor: the gaur (another relative of the aurochs) of Indian and Burma. Still confined as a domestic animal to that area.

compare wolves, the wild ancestors of domestic dogs, with the many breeds of dogs. Some dogs are much bigger than wolves (Great Danes), while others are much smaller (Pekingese). Some are slimmer and built for racing (greyhounds), while others are short-legged and useless for racing (dachshunds). They vary enormously in hair form and color, and some are even hairless. Polynesians and Aztecs developed dog breeds specifically raised for food. Comparing a dachshund with a wolf, you wouldn't even suspect that the former had been derived from the latter if you didn't already know it.

THE WILD ANCESTORS of the Ancient Fourteen were spread unevenly over the globe. South America had only one such ancestor, which gave rise to the llama and alpaca. North America, Australia, and sub-Saharan Africa had none at all. The lack of domestic mammals indigenous to sub-Saharan Africa is especially astonishing, since a main reason why tourists visit Africa today is to see its abundant and diverse wild mammals. In contrast, the wild ancestors of 13 of the Ancient Fourteen (including all of the Major Five) were confined to Eurasia. (As elsewhere in this book, my use of the term "Eurasia" includes in several cases North Africa, which biogeographically and in many aspects of human culture is more closely related to Eurasia than to sub-Saharan Africa.)

Of course, not all 13 of these wild ancestral species occurred together throughout Eurasia. No area had all 13, and some of the wild ancestors were quite local, such as the yak, confined in the wild to Tibet and adjacent highland areas. However, many parts of Eurasia did have quite a few of these 13 species living together in the same area: for example, seven of the wild ancestors occurred in Southwest Asia.

This very unequal distribution of wild ancestral species among the con-

tinents became an important reason why Eurasians, rather than peoples of other continents, were the ones to end up with guns, germs, and steel. How can we explain the concentration of the Ancient Fourteen in Eurasia?

One reason is simple. Eurasia has the largest number of big terrestrial wild mammal species, whether or not ancestral to a domesticated species. Let's define a "candidate for domestication" as any terrestrial herbivorous or omnivorous mammal species (one not predominantly a carnivore) weighing on the average over 100 pounds (45 kilograms). Table 9.2 shows that Eurasia has the most candidates, 72 species, just as it has the most species in many other plant and animal groups. That's because Eurasia is the world's largest landmass, and it's also very diverse ecologically, with habitats ranging from extensive tropical rain forests, through temperate forests, deserts, and marshes, to equally extensive tundras. Sub-Saharan Africa has fewer candidates, 51 species, just as it has fewer species in most other plant and animal groups—because it's smaller and ecologically less diverse than Eurasia. Africa has smaller areas of tropical rain forest than does Southeast Asia, and no temperate habitats at all beyond latitude 37 degrees. As I discussed in Chapter 1, the Americas may formerly have had almost as many candidates as Africa, but most of America's big wild mammals (including its horses, most of its camels, and other species likely to have been domesticated had they survived) became extinct about 13,000 years ago. Australia, the smallest and most isolated continent, has always had far fewer species of big wild mammals than has Eurasia, Africa, or the Americas. Just as in the Americas, in Australia all of those few candidates

TABLE 9.2 Mammalian Candidates for Domestication

|                                       | Continent |                    |                        |
|---------------------------------------|-----------|--------------------|------------------------|
|                                       | Eurasia   | Sub-Saharan Africa | The Americas Australia |
| Candidates                            | 72        | 51                 | 24 1                   |
| Domesticated species                  | 13        | 0                  | 1 0                    |
| Percentage of candidates domesticated | 18%       | 0%                 | 4% 0%                  |

A "candidate" is defined as a species of terrestrial, herbivorous or omnivorous, wild mammal weighing on the average over 100 pounds.

except the red kangaroo became extinct around the time of the continent's first colonization by humans.

Thus, part of the explanation for Eurasia's having been the main site of big mammal domestication is that it was the continent with the most candidate species of wild mammals to start out with, and lost the fewest candidates to extinction in the last 40,000 years. But the numbers in Table 9.2 warn us that that's not the whole explanation. It's also true that the *percentage* of candidates actually domesticated is highest in Eurasia (18 percent), and is especially low in sub-Saharan Africa (no species domesticated out of 51 candidates!). Particularly surprising is the large number of species of African and American mammals that were never domesticated, despite their having Eurasian close relatives or counterparts that were domesticated. Why were Eurasia's horses domesticated, but not Africa's zebras? Why Eurasia's pigs, but not American peccaries or Africa's three species of true wild pigs? Why Eurasia's five species of wild cattle (aurochs, water buffalo, yak, gaur, banteng), but not the African buffalo or American bison? Why the Asian mouflon sheep (ancestor of our domestic sheep), but not North American bighorn sheep?

**D**ID ALL THOSE peoples of Africa, the Americas, and Australia, despite their enormous diversity, nonetheless share some cultural obstacles to domestication not shared with Eurasian peoples? For example, did Africa's abundance of big wild mammals, available to kill by hunting, make it superfluous for Africans to go to the trouble of tending domestic stock?

The answer to that question is unequivocal: No! The interpretation is refuted by five types of evidence: rapid acceptance of Eurasian domesticates by non-Eurasian peoples, the universal human penchant for keeping pets, the rapid domestication of the Ancient Fourteen, the repeated independent domestications of some of them, and the limited successes of modern efforts at further domestications.

First, when Eurasia's Major Five domestic mammals reached sub-Saharan Africa, they were adopted by the most diverse African peoples wherever conditions permitted. Those African herders thereby achieved a huge advantage over African hunter-gatherers and quickly displaced them. In particular, Bantu farmers who acquired cows and sheep spread out of their homeland in West Africa and within a short time overran the former hunter-gatherers in most of the rest of sub-Saharan Africa. Even without

acquiring crops, Khoisan peoples who acquired cows and sheep around 2,000 years ago displaced Khoisan hunter-gatherers over much of southern Africa. The arrival of the domestic horse in West Africa transformed warfare there and turned the area into a set of kingdoms dependent on cavalry. The only factor that prevented horses from spreading beyond West Africa was trypanosome diseases borne by tsetse flies.

The same pattern repeated itself elsewhere in the world, whenever peoples lacking native wild mammal species suitable for domestication finally had the opportunity to acquire Eurasian domestic animals. European horses were eagerly adopted by Native Americans in both North and South America, within a generation of the escape of horses from European settlements. For example, by the 19th century North America's Great Plains Indians were famous as expert horse-mounted warriors and bison hunters, but they did not even obtain horses until the late 17th century. Sheep acquired from Spaniards similarly transformed Navajo Indian society and led to, among other things, the weaving of the beautiful woolen blankets for which the Navajo have become renowned. Within a decade of Tasmania's settlement by Europeans with dogs, Aboriginal Tasmanians, who had never before seen dogs, began to breed them in large numbers for use in hunting. Thus, among the thousands of culturally diverse native peoples of Australia, the Americas, and Africa, no universal cultural taboo stood in the way of animal domestication.

Surely, if some local wild mammal species of those continents had been domesticable, some Australian, American, and African peoples would have domesticated them and gained great advantage from them, just as they benefited from the Eurasian domestic animals that they immediately adopted when those became available. For instance, consider all the peoples of sub-Saharan Africa living within the range of wild zebras and buffalo. Why wasn't there at least one African hunter-gatherer tribe that domesticated those zebras and buffalo and that thereby gained sway over other Africans, without having to await the arrival of Eurasian horses and cattle? All these facts indicate that the explanation for the lack of native mammal domestication outside Eurasia lay with the locally available wild mammals themselves, not with the local peoples.

A SECOND TYPE of evidence for the same interpretation comes from pets. Keeping wild animals as pets, and taming them, constitute an initial

stage in domestication. But pets have been reported from virtually all traditional human societies on all continents. The variety of wild animals thus tamed is far greater than the variety eventually domesticated, and includes some species that we would scarcely have imagined as pets.

For example, in the New Guinea villages where I work, I often see people with pet kangaroos, possums, and birds ranging from flycatchers to ospreys. Most of these captives are eventually eaten, though some are kept just as pets. New Guineans even regularly capture chicks of wild cassowaries (an ostrich-like large, flightless bird) and raise them to eat as a delicacy—even though captive adult cassowaries are extremely dangerous and now and then disembowel village people. Some Asian peoples tame eagles for use in hunting, although those powerful pets have also been known on occasion to kill their human handlers. Ancient Egyptians and Assyrians, and modern Indians, tamed cheetahs for use in hunting. Paintings made by ancient Egyptians show that they further tamed (not surprisingly) hoofed mammals such as gazelles and hartebeests, birds such as cranes, more surprisingly giraffes (which can be dangerous), and most astonishingly hyenas. African elephants were tamed in Roman times despite the obvious danger, and Asian elephants are still being tamed today. Perhaps the most unlikely pet is the European brown bear (the same species as the American grizzly bear), which the Ainu people of Japan *regularly* captured as young animals, tamed, and reared to kill and eat in a ritual ceremony.

Thus, many wild animal species reached the first stage in the sequence of animal-human relations leading to domestication, but only a few emerged at the other end of that sequence as domestic animals. Over a century ago, the British scientist Francis Galton summarized this discrepancy succinctly: "It would appear that every wild animal has had its chance of being domesticated, that [a] few . . . were domesticated long ago, but that the large remainder, who failed sometimes in only one small particular, are destined to perpetual wildness."

DATES OF DOMESTICATION provide a third line of evidence confirming Galton's view that early herding peoples quickly domesticated all big mammal species suitable for being domesticated. All species for whose dates of domestication we have archaeological evidence were domesticated between about 8000 and 2500 B.C.—that is, within the first few thousand years of the sedentary farming-herding societies that arose after the end

TABLE 9.3 Approximate Dates of First Attested Evidence for Domestication of Large Mammal Species

| Species        | Date (B.C.) | Place                                  |
|----------------|-------------|----------------------------------------|
| Dog            | 10,000      | Southwest Asia, China, North America   |
| Sheep          | 8,000       | Southwest Asia                         |
| Goat           | 8,000       | Southwest Asia                         |
| Pig            | 8,000       | China, Southwest Asia                  |
| Cow            | 6,000       | Southwest Asia, India, (?)North Africa |
| Horse          | 4,000       | Ukraine                                |
| Donkey         | 4,000       | Egypt                                  |
| Water buffalo  | 4,000       | China?                                 |
| Llama / alpaca | 3,500       | Andes                                  |
| Bactrian camel | 2,500       | Central Asia                           |
| Arabian camel  | 2,500       | Arabia                                 |

For the other four domesticated large mammal species—reindeer, yak, gaur, and banteng—there is as yet little evidence concerning the date of domestication. Dates and places shown are merely the earliest ones attested to date; domestication may actually have begun earlier and at a different location.

of ancient humans. Europeans today are heirs to one of the longest traditions of animal domestication on Earth—that which began in Southwest Asia around 10,000 years ago. Since the fifteenth century, Europeans have spread around the globe and encountered wild mammal species not found in Europe. European settlers, such as those that I encountered in New Guinea with pet kangaroos and possums, have tamed or made pets of many local mammals, just as have indigenous peoples. European herders and farmers emigrating to other continents have also made serious efforts to domesticate some local species.

In the 19th and 20th centuries at least six large mammals—the eland, elk, moose, musk ox, zebra, and American bison—have been the subjects of especially well-organized projects aimed at domestication, carried out by modern scientific animal breeders and geneticists. For example, eland, the largest African antelope, have been undergoing selection for meat quality and milk quantity in the Askaniya-Nova Zoological Park in the

of the last Ice Age. As summarized in Table 9.3, the era of big mammal domestication began with the sheep, goat, and pig and ended with camels. Since 2500 B.C. there have been no significant additions.

It's true, of course, that some small mammals were first domesticated long after 2500 B.C. For example, rabbits were not domesticated for food until the Middle Ages, mice and rats for laboratory research not until the 20th century, and hamsters for pets not until the 1930s. The continuing development of domesticated small mammals isn't surprising, because there are literally thousands of wild species as candidates, and because they were of too little value to traditional societies to warrant the effort of raising them. But big mammal domestication virtually ended 4,500 years ago. By then, all of the world's 148 candidate big species must have been tested innumerable times, with the result that only a few passed the test and no other suitable ones remained.

STILL A FOURTH line of evidence that some mammal species are much more suitable than others is provided by the repeated independent domestications of the same species. Genetic evidence based on the portions of our genetic material known as mitochondrial DNA recently confirmed, as had long been suspected, that humped cattle of India and humpless European cattle were derived from two separate populations of wild ancestral cattle that had diverged hundreds of thousands of years ago. That is, Indian peoples domesticated the local Indian subspecies of wild aurochs, Southwest Asians independently domesticated their own Southwest Asian subspecies of aurochs, and North Africans may have independently domesticated the North African aurochs.

Similarly, wolves were independently domesticated to become dogs in the Americas and probably in several different parts of Eurasia, including China and Southwest Asia. Modern pigs are derived from independent sequences of domestication in China, western Eurasia, and possibly other areas as well. These examples reemphasize that the same few suitable wild species attracted the attention of many different human societies.

THE FAILURES OF modern efforts provide a final type of evidence that past failures to domesticate the large residue of wild candidate species arose from shortcomings of those species, rather than from shortcomings

Ukraine, as well as in England, Kenya, Zimbabwe, and South Africa; an experimental farm for elk (red deer, in British terminology) has been operated by the Rowett Research Institute at Aberdeen, Scotland; and an experimental farm for moose has operated in the Pechero-Ilych National Park in Russia. Yet these modern efforts have achieved only very limited successes. While bison meat occasionally appears in some U.S. supermarkets, and while moose have been ridden, milked, and used to pull sleds in Sweden and Russia, none of these efforts has yielded a result of sufficient economic value to attract many ranchers. It is especially striking that recent attempts to domesticate eland within Africa itself, where its disease resistance and climate tolerance would give it a big advantage over introduced Eurasian wild stock susceptible to African diseases, have not caught on.

Thus, neither indigenous herders with access to candidate species over thousands of years, nor modern geneticists, have succeeded in making useful domesticates of large mammals beyond the Ancient Fourteen, which were domesticated by at least 4,500 years ago. Yet scientists today could undoubtedly, if they wished, fulfill for many species that part of the definition of domestication that specifies the control of breeding and food supply. For example, the San Diego and Los Angeles zoos are now subjecting the last surviving California condors to a more draconian control of breeding than that imposed upon any domesticated species. All individual condors have been genetically identified, and a computer program determines which male shall mate with which female in order to achieve human goals (in this case, to maximize genetic diversity and thereby preserve this endangered bird). Zoos are conducting similar breeding programs for many other threatened species, including gorillas and rhinos. But the zoos' rigorous selection of California condors shows no prospects of yielding an economically useful product. Nor do zoos' efforts with rhinos, although rhinos offer up to over three tons of meat on the hoof. As we shall now see, rhinos (and most other big mammals) present insuperable obstacles to domestication.

IN ALL, OF the world's 148 big wild terrestrial herbivorous mammals—the candidates for domestication—only 14 passed the test. Why did the other 134 species fail? To which conditions was Francis Galton referring, when he spoke of those other species as "destined to perpetual wildness"?

The answer follows from the *Anna Karenina* principle. To be domesticated, a candidate wild species must possess many different characteristics. Lack of any single required characteristic dooms efforts at domestication, just as it dooms efforts at building a happy marriage. Playing marriage counselor to the zebra/human couple and other ill-sorted pairs, we can recognize at least six groups of reasons for failed domestication.

*Diet.* Every time that an animal eats a plant or another animal, the conversion of food biomass into the consumer's biomass involves an efficiency of much less than 100 percent: typically around 10 percent. That is, it takes around 10,000 pounds of corn to grow a 1,000-pound cow. If instead you want to grow 1,000 pounds of carnivore, you have to feed it 10,000 pounds of herbivore grown on 100,000 pounds of corn. Even among herbivores and omnivores, many species, like koalas, are too finicky in their plant preferences to recommend themselves as farm animals.

As a result of this fundamental inefficiency, no mammalian carnivore has ever been domesticated for food. (No, it's not because its meat would be tough or tasteless: we eat carnivorous wild fish all the time, and I can personally attest to the delicious flavor of lion burger.) The nearest thing to an exception is the dog, originally domesticated as a sentinel and hunting companion, but breeds of dogs were developed and raised for food in Aztec Mexico, Polynesia, and ancient China. However, regular dog eating has been a last resort of meat-deprived human societies: the Aztecs had no other domestic mammal, and the Polynesians and ancient Chinese had only pigs and dogs. Human societies blessed with domestic herbivorous mammals have not bothered to eat dogs, except as an uncommon delicacy (as in parts of Southeast Asia today). In addition, dogs are not strict carnivores but omnivores: if you are so naive as to think that your beloved pet dog is really a meat eater, just read the list of ingredients on your bag of dog food. The dogs that the Aztecs and Polynesians reared for food were efficiently fattened on vegetables and garbage.

*Growth Rate.* To be worth keeping, domesticates must also grow quickly. That eliminates gorillas and elephants, even though they are vegetarians with admirably nonfinicky food preferences and represent a lot of meat. What would-be gorilla or elephant rancher would wait 15 years for his herd to reach adult size? Modern Asians who want work elephants find it much cheaper to capture them in the wild and tame them.

*Problems of Captive Breeding.* We humans don't like to have sex under the watchful eyes of others; some potentially valuable animal species don't

like to, either. That's what derailed attempts to domesticate cheetahs, the swiftest of all land animals, despite our strong motivation to do so for thousands of years.

As I already mentioned, tame cheetahs were prized by ancient Egyptians and Assyrians and modern Indians as hunting animals infinitely superior to dogs. One Mogul emperor of India kept a stable of a thousand cheetahs. But despite those large investments that many wealthy princes made, all of their cheetahs were tamed ones caught in the wild. The princes' efforts to breed cheetahs in captivity failed, and not until 1960 did even biologists in modern zoos achieve their first successful cheetah birth. In the wild, several cheetah brothers chase a female for several days, and that rough courtship over large distances seems to be required to get the female to ovulate or to become sexually receptive. Cheetahs usually refuse to carry out that elaborate courtship ritual inside a cage.

A similar problem has frustrated schemes to breed the vicuña, an Andean wild camel whose wool is prized as the finest and lightest of any animal's. The ancient Incas obtained vicuña wool by driving wild vicuñas into corrals, shearing them, and then releasing them alive. Modern merchants wanting this luxury wool have had to resort either to this same method or simply to killing wild vicuñas. Despite strong incentives of money and prestige, all attempts to breed vicuñas for wool production in captivity have failed, for reasons that include vicuñas' long and elaborate courtship ritual before mating, a ritual inhibited in captivity; male vicuñas' fierce intolerance of each other; and their requirement for both a year-round feeding territory and a separate year-round sleeping territory.

*Nasty Disposition.* Naturally, almost any mammal species that is sufficiently large is capable of killing a human. People have been killed by pigs, horses, camels, and cattle. Nevertheless, some large animals have much nastier dispositions and are more incurably dangerous than are others. Tendencies to kill humans have disqualified many otherwise seemingly ideal candidates for domestication.

One obvious example is the grizzly bear. Bear meat is an expensive delicacy, grizzlies weigh up to 1,700 pounds, they are mainly vegetarians (though also formidable hunters), their vegetable diet is very broad, they thrive on human garbage (thereby creating big problems in Yellowstone and Glacier National Parks), and they grow relatively fast. If they would behave themselves in captivity, grizzlies would be a fabulous meat production animal. The Ainu people of Japan made the experiment by routinely

rearing grizzly cubs as part of a ritual. For understandable reasons, though, the Ainu found it prudent to kill and eat the cubs at the age of one year. Keeping grizzly bears for longer would be suicidal; I am not aware of any adult that has been tamed.

Another otherwise suitable candidate that disqualifies itself for equally obvious reasons is the African buffalo. It grows quickly up to a weight of a ton and lives in herds that have a well-developed dominance hierarchy, a trait whose virtues will be discussed below. But the African buffalo is considered the most dangerous and unpredictable large mammal of Africa. Anyone insane enough to try to domesticate it either died in the effort or was forced to kill the buffalo before it got too big and nasty. Similarly, hippos, as four-ton vegetarians, would be great barnyard animals if they weren't so dangerous. They kill more people each year than do any other African mammals, including even lions.

Few people would be surprised at the disqualification of those notoriously ferocious candidates. But there are other candidates whose dangers are not so well known. For instance, the eight species of wild equids (horses and their relatives) vary greatly in disposition, even though all eight are genetically so close to each other that they will interbreed and produce healthy (though usually sterile) offspring. Two of them, the horse and the North African ass (ancestor of the donkey), were successfully domesticated. Closely related to the North African ass is the Asiatic ass, also known as the onager. Since its homeland includes the Fertile Crescent, the cradle of Western civilization and animal domestication, ancient peoples must have experimented extensively with onagers. We know from Sumerian and later depictions that onagers were regularly hunted, as well as captured and hybridized with donkeys and horses. Some ancient depictions of horselike animals used for riding or for pulling carts may refer to onagers. However, all writers about them, from Romans to modern zookeepers, decry their irascible temper and their nasty habit of biting people. As a result, although similar in other respects to ancestral donkeys, onagers have never been domesticated.

Africa's four species of zebras are even worse. Efforts at domestication went as far as hitching them to carts: they were tried out as draft animals in 19th-century South Africa, and the eccentric Lord Walter Rothschild drove through the streets of London in a carriage pulled by zebras. Alas, zebras become impossibly dangerous as they grow older. (That's not to deny that many individual horses are also nasty, but zebras and onagers

are much more uniformly so.) Zebras have the unpleasant habit of biting a person and not letting go. They thereby injure even more American zookeepers each year than do tigers! Zebras are also virtually impossible to lasso with a rope—even for cowboys who win rodeo championships by lassoing horses—because of their unfailing ability to watch the rope noose fly toward them and then to duck their head out of the way.

Hence it has rarely (if ever) been possible to saddle or ride a zebra, and South Africans' enthusiasm for their domestication waned. Unpredictably aggressive behavior on the part of a large and potentially dangerous mammal is also part of the reason why the initially so promising modern experiments in domesticating elk and eland have not been more successful.

*Tendency to Panic.* Big mammalian herbivore species react to danger from predators or humans in different ways. Some species are nervous, fast, and programmed for instant flight when they perceive a threat. Other species are slower, less nervous, seek protection in herds, stand their ground when threatened, and don't run until necessary. Most species of deer and antelope (with the conspicuous exception of reindeer) are of the former type, while sheep and goats are of the latter.

Naturally, the nervous species are difficult to keep in captivity. If put into an enclosure, they are likely to panic, and either die of shock or batter themselves to death against the fence in their attempts to escape. That's true, for example, of gazelles, which for thousands of years were the most frequently hunted game species in some parts of the Fertile Crescent. There is no mammal species that the first settled peoples of that area had more opportunity to domesticate than gazelles. But no gazelle species has ever been domesticated. Just imagine trying to herd an animal that bolts, blindly bashes itself against walls, can leap up to nearly 30 feet, and can run at a speed of 50 miles per hour!

*Social Structure.* Almost all species of domesticated large mammals prove to be ones whose wild ancestors share three social characteristics: they live in herds; they maintain a well-developed dominance hierarchy among herd members; and the herds occupy overlapping home ranges rather than mutually exclusive territories. For example, herds of wild horses consist of one stallion, up to half a dozen mares, and their foals. Mare A is dominant over mares B, C, D, and E; mare B is submissive to A but dominant over C, D, and E; C is submissive to B and A but dominant over D and E; and so on. When the herd is on the move, its members maintain a stereotyped order: in the rear, the stallion; in the front, the top-

ranking female, followed by her foals in order of age, with the youngest first; and behind her, the other mares in order of rank, each followed by her foals in order of age. In that way, many adults can coexist in the herd without constant fighting and with each knowing its rank.

That social structure is ideal for domestication, because humans in effect take over the dominance hierarchy. Domestic horses of a pack line follow the human leader as they would normally follow the top-ranking female. Herds or packs of sheep, goats, cows, and ancestral dogs (wolves) have a similar hierarchy. As young animals grow up in such a herd, they imprint on the animals that they regularly see nearby. Under wild conditions those are members of their own species, but captive young herd animals also see humans nearby and imprint on humans as well.

Such social animals lend themselves to herding. Since they are tolerant of each other, they can be bunched up. Since they instinctively follow a dominant leader and will imprint on humans as that leader, they can readily be driven by a shepherd or sheepdog. Herd animals do well when penned in crowded conditions, because they are accustomed to living in densely packed groups in the wild.

In contrast, members of most solitary territorial animal species cannot be herded. They do not tolerate each other, they do not imprint on humans, and they are not instinctively submissive. Who ever saw a line of cats (solitary and territorial in the wild) following a human or allowing themselves to be herded by a human? Every cat lover knows that cats are not submissive to humans in the way dogs instinctively are. Cats and ferrets are the sole territorial mammal species that were domesticated, because our motive for doing so was not to herd them in large groups raised for food but to keep them as solitary hunters or pets.

While most solitary territorial species thus haven't been domesticated, it's not conversely the case that most herd species can be domesticated. Most can't, for one of several additional reasons.

First, herds of many species don't have overlapping home ranges but instead maintain exclusive territories against other herds. It's no more possible to pen two such herds together than to pen two males of a solitary species.

Second, many species that live in herds for part of the year are territorial in the breeding season, when they fight and do not tolerate each other's presence. That's true of most deer and antelope species (again with the exception of reindeer), and it's one of the main factors that has disqualified

all the social antelope species for which Africa is famous from being domesticated. While one's first association to African antelope is "vast dense herds spreading across the horizon," in fact the males of those herds space themselves into territories and fight fiercely with each other when breeding. Hence those antelope cannot be maintained in crowded enclosures in captivity, as can sheep or goats or cattle. Territorial behavior similarly combines with a fierce disposition and a slow growth rate to banish rhinos from the farmyard.

Finally, many herd species, including again most deer and antelope, do not have a well-defined dominance hierarchy and are not instinctively prepared to become imprinted on a dominant leader (hence to become misimprinted on humans). As a result, though many deer and antelope species have been tamed (think of all those true Bambi stories), one never sees such tame deer and antelope driven in herds like sheep. That problem also derailed domestication of North American bighorn sheep, which belong to the same genus as Asiatic mouflon sheep, ancestor of our domestic sheep. Bighorn sheep are suitable to us and similar to mouflons in most respects except a crucial one: they lack the mouflon's stereotypical behavior whereby some individuals behave submissively toward other individuals whose dominance they acknowledge.

LET'S NOW RETURN to the problem I posed at the outset of this chapter. Initially, one of the most puzzling features of animal domestication is the seeming arbitrariness with which some species have been domesticated while their close relatives have not. It turns out that all but a few candidates for domestication have been eliminated by the *Anna Karenina* principle. Humans and most animal species make an unhappy marriage, for one or more of many possible reasons: the animal's diet, growth rate, mating habits, disposition, tendency to panic, and several distinct features of social organization. Only a small percentage of wild mammal species ended up in happy marriages with humans, by virtue of compatibility on all those separate counts.

Eurasian peoples happened to inherit many more species of domesticable large wild mammalian herbivores than did peoples of the other continents. That outcome, with all of its momentous advantages for Eurasian societies, stemmed from three basic facts of mammalian geography, history, and biology. First, Eurasia, befitting its large area and ecological

diversity, started out with the most candidates. Second, Australia and the Americas, but not Eurasia or Africa, lost most of their candidates in a massive wave of late-Pleistocene extinctions—possibly because the mammals of the former continents had the misfortune to be first exposed to humans suddenly and late in our evolutionary history, when our hunting skills were already highly developed. Finally, a higher percentage of the surviving candidates proved suitable for domestication on Eurasia than on the other continents. An examination of the candidates that were never domesticated, such as Africa's big herd-forming mammals, reveals particular reasons that disqualified each of them. Thus, Tolstoy would have approved of the insight offered in another context by an earlier author, Saint Matthew: "Many are called, but few are chosen."

## CHAPTER 10

# SPACIOUS SKIES AND TILTED AXES

ON THE MAP OF THE WORLD ON PAGE 177 (FIGURE 10.1), compare the shapes and orientations of the continents. You'll be struck by an obvious difference. The Americas span a much greater distance north-south (9,000 miles) than east-west: only 3,000 miles at the widest, narrowing to a mere 40 miles at the Isthmus of Panama. That is, the major axis of the Americas is north-south. The same is also true, though to a less extreme degree, for Africa. In contrast, the major axis of Eurasia is east-west. What effect, if any, did those differences in the orientation of the continents' axes have on human history?

This chapter will be about what I see as their enormous, sometimes tragic, consequences. Axis orientations affected the rate of spread of crops and livestock, and possibly also of writing, wheels, and other inventions. That basic feature of geography thereby contributed heavily to the very different experiences of Native Americans, Africans, and Eurasians in the last 500 years.

FOOD PRODUCTION'S SPREAD proves as crucial to understanding geographic differences in the rise of guns, germs, and steel as did its origins, which we considered in the preceding chapters. That's because, as we

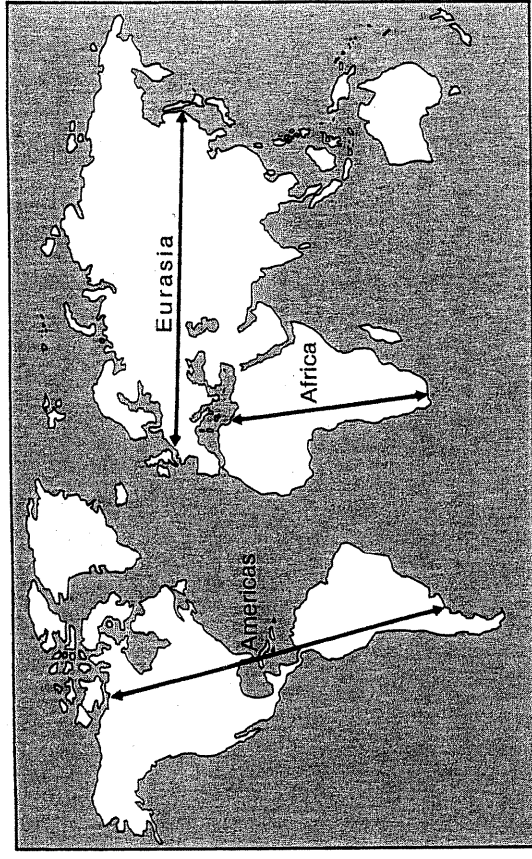


Figure 10.1. Major axes of the continents.

saw in Chapter 5, there were no more than nine areas of the globe, perhaps as few as five, where food production arose independently. Yet, already in prehistoric times, food production became established in many other regions besides those few areas of origins. All those other areas became food producing as a result of the spread of crops, livestock, and knowledge of how to grow them and, in some cases, as a result of migrations of farmers and herders themselves.

The main such spreads of food production were from Southwest Asia to Europe, Egypt and North Africa, Ethiopia, Central Asia, and the Indus Valley; from the Sahel and West Africa to East and South Africa; from China to tropical Southeast Asia, the Philippines, Indonesia, Korea, and Japan; and from Mesoamerica to North America. Moreover, food production even in its areas of origin became enriched by the addition of crops, livestock, and techniques from other areas of origin.

Just as some regions proved much more suitable than others for the origins of food production, the ease of its spread also varied greatly around the world. Some areas that are ecologically very suitable for food production never acquired it in prehistoric times at all, even though areas of prehistoric food production existed nearby. The most conspicuous such examples are the failure of both farming and herding to reach Native

American California from the U.S. Southwest or to reach Australia from New Guinea and Indonesia, and the failure of farming to spread from South Africa's Natal Province to South Africa's Cape. Even among all those areas where food production did spread in the prehistoric era, the rates and dates of spread varied considerably. At the one extreme was its rapid spread along east-west axes: from Southwest Asia both west to Europe and Egypt and east to the Indus Valley (at an average rate of about 0.7 miles per year); and from the Philippines east to Polynesia (at 3.2 miles per year). At the opposite extreme was its slow spread along north-south axes: at less than 0.5 miles per year, from Mexico northward to the U.S. Southwest; at less than 0.3 miles per year, for corn and beans from Mexico northward to become productive in the eastern United States around A.D. 900; and at 0.2 miles per year, for the llama from Peru north to Ecuador. These differences could be even greater if corn was not domesticated in Mexico as late as 3500 B.C., as I assumed conservatively for these calculations, and as some archaeologists now assume, but if it was instead domesticated considerably earlier, as most archaeologists used to assume (and many still do).

There were also great differences in the completeness with which suites of crops and livestock spread, again implying stronger or weaker barriers to their spreading. For instance, while most of Southwest Asia's founder crops and livestock did spread west to Europe and east to the Indus Valley, neither of the Andes' domestic mammals (the llama / alpaca and the guinea pig) ever reached Mesoamerica in pre-Columbian times. That astonishing failure cries out for explanation. After all, Mesoamerica did develop dense farming populations and complex societies, so there can be no doubt that Andean domestic animals (if they had been available) would have been valuable for food, transport, and wool. Except for dogs, Mesoamerica was utterly without indigenous mammals to fill those needs. Some South American crops nevertheless did succeed in reaching Mesoamerica, such as manioc, sweet potatoes, and peanuts. What selective barrier let those crops through but screened out llamas and guinea pigs?

A subtler expression of this geographically varying ease of spread is the phenomenon termed preemptive domestication. Most of the wild plant species from which our crops were derived vary genetically from area to area, because alternative mutations had become established among the wild ancestral populations of different areas. Similarly, the changes required to transform wild plants into crops can in principle be brought

about by alternative new mutations or alternative courses of selection to yield equivalent results. In this light, one can examine a crop widespread in prehistoric times and ask whether all of its varieties show the same wild mutation or same transforming mutation. The purpose of this examination is to try to figure out whether the crop was developed in just one area or else independently in several areas.

If one carries out such a genetic analysis for major ancient New World crops, many of them prove to include two or more of those alternative wild variants, or two or more of those alternative transforming mutations. This suggests that the crop was domesticated independently in at least two different areas, and that some varieties of the crop inherited the particular mutation of one area while other varieties of the same crop inherited the mutation of another area. On this basis, botanists conclude that lima beans (*Phaseolus lunatus*), common beans (*Phaseolus vulgaris*), and chili peppers of the *Capsicum annuum / chinense* group were all domesticated on at least two separate occasions, once in Mesoamerica and once in South America; and that the squash *Cucurbita pepo* and the seed plant goosefoot were also domesticated independently at least twice, once in Mesoamerica and once in the eastern United States. In contrast, most ancient Southwest Asian crops exhibit just one of the alternative wild variants or alternative transforming mutations, suggesting that all modern varieties of that particular crop stem from only a single domestication.

What does it imply if the same crop has been repeatedly and independently domesticated in several different parts of its wild range, and not just once and in a single area? We have already seen that plant domestication involves the modification of wild plants so that they become more useful to humans by virtue of larger seeds, a less bitter taste, or other qualities. Hence if a productive crop is already available, incipient farmers will surely proceed to grow it rather than start all over again by gathering its not yet so useful wild relative and redomesticating it. Evidence for just a single domestication thus suggests that, once a wild plant had been domesticated, the crop spread quickly to other areas throughout the wild plant's range, preempting the need for other independent domestications of the same plant. However, when we find evidence that the same wild ancestor was domesticated independently in different areas, we infer that the crop spread too slowly to preempt its domestication elsewhere. The evidence for predominantly single domestications in Southwest Asia, but frequent multiple domestications in the Americas, might thus provide

nore subtle evidence that crops spread more easily out of Southwest Asia than in the Americas.

Rapid spread of a crop may preempt domestication not only of the same wild ancestral species somewhere else but also of related wild species. If you're already growing good peas, it's of course pointless to start from scratch to domesticate the same wild ancestral pea again, but it's also pointless to domesticate closely related wild pea species that for farmers are virtually equivalent to the already domesticated pea species. All of Southwest Asia's founder crops preempted domestication of any of their close relatives throughout the whole expanse of western Eurasia. In contrast, the New World presents many cases of equivalent and closely related, but nevertheless distinct, species having been domesticated in Mesoamerica and South America. For instance, 95 percent of the cotton grown in the world today belongs to the cotton species *Gossypium hirsutum*, which was domesticated in prehistoric times in Mesoamerica. However, prehistoric South American farmers instead grew the related cotton *Gossypium barbadense*. Evidently, Mesoamerican cotton had such difficulty reaching South America that it failed in the prehistoric era to preempt the domestication of a different cotton species there (and vice versa). Chili peppers, squashes, amaranths, and chenopods are other crops of which different but related species were domesticated in Mesoamerica and South America, since no species was able to spread fast enough to preempt the others.

We thus have many different phenomena converging on the same conclusion: that food production spread more readily out of Southwest Asia than in the Americas, and possibly also than in sub-Saharan Africa. Those phenomena include food production's complete failure to reach some ecologically suitable areas; the differences in its rate and selectivity of spread; and the differences in whether the earliest domesticated crops preempted redomestications of the same species or domestications of close relatives. What was it about the Americas and Africa that made the spread of food production more difficult there than in Eurasia?

TO ANSWER THIS question, let's begin by examining the rapid spread of food production out of Southwest Asia (the Fertile Crescent). Soon after food production arose there, somewhat before 8000 B.C., a centrifugal wave of it appeared in other parts of western Eurasia and North Africa

farther and farther removed from the Fertile Crescent, to the west and east. On this page I have redrawn the striking map (Figure 10.2) assembled by the geneticist Daniel Zohary and botanist Maria Hopf, in which they illustrate how the wave had reached Greece and Cyprus and the Indian subcontinent by 6500 B.C., Egypt soon after 6000 B.C., central Europe by 5400 B.C., southern Spain by 5200 B.C., and Britain around 3500 B.C. In each of those areas, food production was initiated by some of the same suite of domestic plants and animals that launched it in the Fertile Crescent. In addition, the Fertile Crescent package penetrated Africa southward to Ethiopia at some still-uncertain date. However, Ethiopia also developed many indigenous crops, and we do not yet know whether it was these crops or the arriving Fertile Crescent crops that launched Ethiopian food production.

The spread of Fertile Crescent crops across western Eurasia

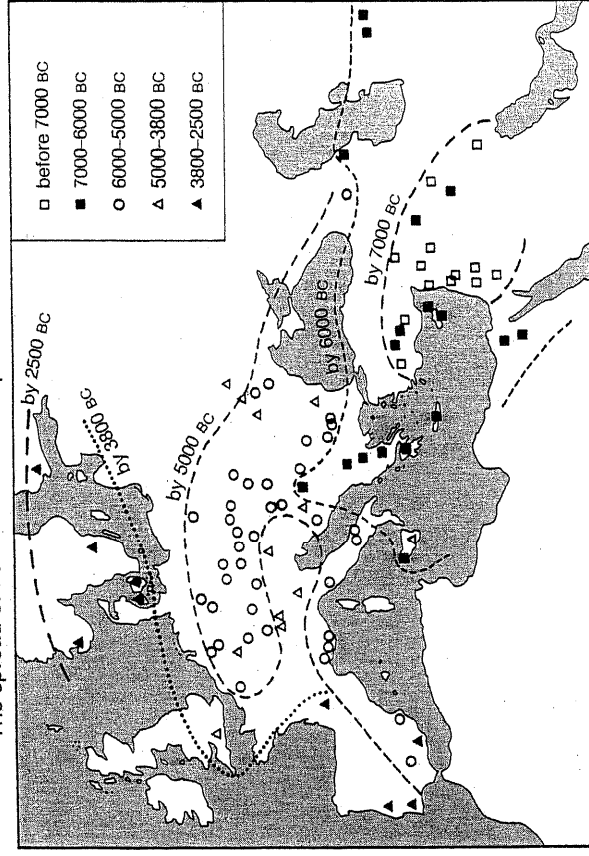


Figure 10.2. The symbols show early radiocarbon-dated sites where remains of Fertile Crescent crops have been found. □ = the Fertile Crescent itself (sites before 7000 B.C.). Note that dates become progressively later as one gets farther from the Fertile Crescent. This map is based on Map 20 of Zohary and Hopf's *Domestication of Plants in the Old World* but substitutes calibrated radiocarbon dates for their uncalibrated dates.

Of course, not all pieces of the package spread to all those outlying areas: for example, Egypt was too warm for einkorn wheat to become established. In some outlying areas, elements of the package arrived at different times: for instance, sheep preceded cereals in southwestern Europe. Some outlying areas went on to domesticate a few local crops of their own, such as poppies in western Europe and watermelons possibly in Egypt. But most food production in outlying areas depended initially on Fertile Crescent domesticates. Their spread was soon followed by that of other innovations originating in or near the Fertile Crescent, including the wheel, writing, metalworking techniques, milking, fruit trees, and beer and wine production.

Why did the same plant package launch food production throughout western Eurasia? Was it because the same set of plants occurred in the wild in many areas, were found useful there just as in the Fertile Crescent, and were independently domesticated? No, that's not the reason. First, many of the Fertile Crescent's founder crops don't even occur in the wild outside Southwest Asia. For instance, none of the eight main founder crops except barley grows wild in Egypt. Egypt's Nile Valley provides an environment similar to the Fertile Crescent's Tigris and Euphrates Valleys. Hence the package that worked well in the latter valleys also worked well enough in the Nile Valley to trigger the spectacular rise of indigenous Egyptian civilization. But the foods to fuel that spectacular rise were originally absent in Egypt. The sphinx and pyramids were built by people fed on crops originally native to the Fertile Crescent, not to Egypt.

Second, even for those crops whose wild ancestor does occur outside of Southwest Asia, we can be confident that the crops of Europe and India were mostly obtained from Southwest Asia and were not local domesticates. For example, wild flax occurs west to Britain and Algeria and east to the Caspian Sea, while wild barley occurs east even to Tibet. However, for most of the Fertile Crescent's founding crops, all cultivated varieties in the world today share only one arrangement of chromosomes out of the multiple arrangements found in the wild ancestor; or else they share only a single mutation (out of many possible mutations) by which the cultivated varieties differ from the wild ancestor in characteristics desirable to humans. For instance, all cultivated peas share the same recessive gene that prevents ripe pods of cultivated peas from spontaneously popping open and spilling their peas, as wild pea pods do.

Evidently, most of the Fertile Crescent's founder crops were never

domesticated again elsewhere after their initial domestication in the Fertile Crescent. Had they been repeatedly domesticated independently, they would exhibit legacies of those multiple origins in the form of varied chromosomal arrangements or varied mutations. Hence these are typical examples of the phenomenon of preemptive domestication that we discussed above. The quick spread of the Fertile Crescent package preempted any possible other attempts, within the Fertile Crescent or elsewhere, to domesticate the same wild ancestors. Once the crop had become available, there was no further need to gather it from the wild and thereby set it on the path to domestication again.

The ancestors of most of the founder crops have wild relatives, in the Fertile Crescent and elsewhere, that would also have been suitable for domestication. For example, peas belong to the genus *Pisum*, which consists of two wild species: *Pisum sativum*, the one that became domesticated to yield our garden peas, and *Pisum fulvum*, which was never domesticated. Yet wild peas of *Pisum fulvum* taste good, either fresh or dried, and are common in the wild. Similarly, wheats, barley, lentil, chickpea, beans, and flax all have numerous wild relatives besides the ones that became domesticated. Some of those related beans and barleys were indeed domesticated independently in the Americas or China, far from the early site of domestication in the Fertile Crescent. But in western Eurasia only one of several potentially useful wild species was domesticated—probably because that one spread so quickly that people soon stopped gathering the other wild relatives and ate only the crop. Again as we discussed above, the crop's rapid spread preempted any possible further attempts to domesticate its relatives, as well as to redomesticate its ancestor.

**WHY WAS THE spread of crops from the Fertile Crescent so rapid?** The answer depends partly on that east-west axis of Eurasia with which I opened this chapter. Localities distributed east and west of each other at the same latitude share exactly the same day length and its seasonal variations. To a lesser degree, they also tend to share similar diseases, regimes of temperature and rainfall, and habitats or biomes (types of vegetation). For example, Portugal, northern Iran, and Japan, all located at about the same latitude but lying successively 4,000 miles east or west of each other, are more similar to each other in climate than each is to a location lying even a mere 1,000 miles due south. On all the continents the habitat type

known as tropical rain forest is confined to within about 10 degrees latitude of the equator, while Mediterranean scrub habitats (such as California's chaparral and Europe's maquis) lie between about 30 and 40 degrees of latitude.

But the germination, growth, and disease resistance of plants are adapted to precisely those features of climate. Seasonal changes of day length, temperature, and rainfall constitute signals that stimulate seeds to germinate, seedlings to grow, and mature plants to develop flowers, seeds, and fruit. Each plant population becomes genetically programmed, through natural selection, to respond appropriately to signals of the seasonal regime under which it has evolved. Those regimes vary greatly with latitude. For example, day length is constant throughout the year at the equator, but at temperate latitudes it increases as the months advance from the winter solstice to the summer solstice, and it then declines again through the next half of the year. The growing season—that is, the months with temperatures and day lengths suitable for plant growth—is shortest at high latitudes and longest toward the equator. Plants are also adapted to the diseases prevalent at their latitude.

Woe betide the plant whose genetic program is mismatched to the latitude of the field in which it is planted! Imagine a Canadian farmer foolish enough to plant a race of corn adapted to growing farther south, in Mexico. The unfortunate corn plant, following its Mexico-adapted genetic program, would prepare to thrust up its shoots in March, only to find itself still buried under 10 feet of snow. Should the plant become genetically reprogrammed so as to germinate at a time more appropriate to Canada—say, late June—the plant would still be in trouble for other reasons. Its genes would be telling it to grow at a leisurely rate, sufficient only to bring it to maturity in five months. That's a perfectly safe strategy in Mexico's mild climate, but in Canada a disastrous one that would guarantee the plant's being killed by autumn frosts before it had produced any mature corn cobs. The plant would also lack genes for resistance to diseases of northern climates, while uselessly carrying genes for resistance to diseases of southern climates. All those features make low-latitude plants poorly adapted to high-latitude conditions, and vice versa. As a consequence, most Fertile Crescent crops grow well in France and Japan but poorly at the equator.

Animals too are adapted to latitude-related features of climate. In that respect we are typical animals, as we know by introspection. Some of us

can't stand cold northern winters with their short days and characteristic germs, while others of us can't stand hot tropical climates with their own characteristic diseases. In recent centuries overseas colonists from cool northern Europe have preferred to emigrate to the similarly cool climates of North America, Australia, and South Africa, and to settle in the cool highlands within equatorial Kenya and New Guinea. Northern Europeans who were sent out to hot tropical lowland areas used to die in droves of diseases such as malaria, to which tropical peoples had evolved some genetic resistance.

That's part of the reason why Fertile Crescent domesticates spread west and east so rapidly: they were already well adapted to the climates of the regions to which they were spreading. For instance, once farming crossed from the plains of Hungary into central Europe around 5400 B.C., it spread so quickly that the sites of the first farmers in the vast area from Poland west to Holland (marked by their characteristic pottery with linear decorations) were nearly contemporaneous. By the time of Christ, cereals of Fertile Crescent origin were growing over the 8,000-mile expanse from the Atlantic coast of Ireland to the Pacific coast of Japan. That west-east expanse of Eurasia is the largest land distance on Earth.

Thus, Eurasia's west-east axis allowed Fertile Crescent crops quickly to launch agriculture over the band of temperate latitudes from Ireland to the Indus Valley, and to enrich the agriculture that arose independently in eastern Asia. Conversely, Eurasian crops that were first domesticated far from the Fertile Crescent but at the same latitudes were able to diffuse back to the Fertile Crescent. Today, when seeds are transported over the whole globe by ship and plane, we take it for granted that our meals are a geographic mishmash. A typical American fast-food restaurant meal would include chicken (first domesticated in China) and potatoes (from the Andes) or corn (from Mexico), seasoned with black pepper (from India) and washed down with a cup of coffee (of Ethiopian origin). Already, though, by 2,000 years ago, Romans were also nourishing themselves with their own hodgepodge of foods that mostly originated elsewhere. Of Roman crops, only oats and poppies were native to Italy. Roman staples were the Fertile Crescent founder package, supplemented by quince (originating in the Caucasus); millet and cumin (domesticated in Central Asia); cucumber, sesame, and citrus fruit (from India); and chicken, rice, apricots, peaches, and foxtail millet (originally from China). Even though Rome's apples were at least native to western Eurasia, they were grown

by means of grafting techniques that had developed in China and spread westward from there.

While Eurasia provides the world's widest band of land at the same latitude, and hence the most dramatic example of rapid spread of domesticates, there are other examples as well. Rivaling in speed the spread of the Fertile Crescent package was the eastward spread of a subtropical package that was initially assembled in South China and that received additions on reaching tropical Southeast Asia, the Philippines, Indonesia, and New Guinea. Within 1,600 years that resulting package of crops (including bananas, taro, and yams) and domestic animals (chickens, pigs, and dogs) had spread more than 5,000 miles eastward into the tropical Pacific to reach the islands of Polynesia. A further likely example is the east-west spread of crops within Africa's wide Sahel zone, but paleobotanists have yet to work out the details.

**C**ONTRAST THE EASE of east-west diffusion in Eurasia with the difficulties of diffusion along Africa's north-south axis. Most of the Fertile Crescent founder crops reached Egypt very quickly and then spread as far south as the cool highlands of Ethiopia, beyond which they didn't spread. South Africa's Mediterranean climate would have been ideal for them, but the 2,000 miles of tropical conditions between Ethiopia and South Africa posed an insuperable barrier. Instead, African agriculture south of the Sahara was launched by the domestication of wild plants (such as sorghum and African yams) indigenous to the Sahel zone and to tropical West Africa, and adapted to the warm temperatures, summer rains, and relatively constant day lengths of those low latitudes.

Similarly, the spread southward of Fertile Crescent domestic animals through Africa was stopped or slowed by climate and disease, especially by trypanosome diseases carried by tsetse flies. The horse never became established farther south than West Africa's kingdoms north of the equator. The advance of cattle, sheep, and goats halted for 2,000 years at the northern edge of the Serengeti Plains, while new types of human economies and livestock breeds were being developed. Not until the period A.D. 1-200, some 8,000 years after livestock were domesticated in the Fertile Crescent, did cattle, sheep, and goats finally reach South Africa. Tropical African crops had their own difficulties spreading south in Africa, arriving in South Africa with black African farmers (the Bantu) just after those

Fertile Crescent livestock did. However, those tropical African crops could never be transmitted across South Africa's Fish River, beyond which they were stopped by Mediterranean conditions to which they were not adapted.

The result was the all-too-familiar course of the last two millennia of South African history. Some of South Africa's indigenous Khoisan peoples (otherwise known as Hottentots and Bushmen) acquired livestock but remained without agriculture. They became outnumbered and were replaced northeast of the Fish River by black African farmers, whose southward spread halted at that river. Only when European settlers arrived by sea in 1652, bringing with them their Fertile Crescent crop package, could agriculture thrive in South Africa's Mediterranean zone. The collisions of all those peoples produced the tragedies of modern South Africa: the quick decimation of the Khoisan by European germs and guns; a century of wars between Europeans and blacks; another century of racial oppression; and now, efforts by Europeans and blacks to seek a new mode of coexistence in the former Khoisan lands.

**C**ONTRAST ALSO THE ease of diffusion in Eurasia with its difficulties along the Americas' north-south axis. The distance between Mesoamerica and South America—say, between Mexico's highlands and Ecuador's—is only 1,200 miles, approximately the same as the distance in Eurasia separating the Balkans from Mesopotamia. The Balkans provided ideal growing conditions for most Mesopotamian crops and livestock, and received those domesticates as a package within 2,000 years of its assembly in the Fertile Crescent. That rapid spread preempted opportunities for domesticating those and related species in the Balkans. Highland Mexico and the Andes would similarly have been suitable for many of each other's crops and domestic animals. A few crops, notably Mexican corn, did indeed spread to the other region in the pre-Columbian era.

But other crops and domestic animals failed to spread between Mesoamerica and South America. The cool highlands of Mexico would have provided ideal conditions for raising llamas, guinea pigs, and potatoes, all domesticated in the cool highlands of the South American Andes. Yet the northward spread of those Andean specialties was stopped completely by the hot intervening lowlands of Central America. Five thousand years after llamas had been domesticated in the Andes, the Olmecs, Maya, Aztecs,

and all other native societies of Mexico remained without pack animals and without any edible domestic mammals except for dogs.

Conversely, domestic turkeys of Mexico and domestic sunflowers of the eastern United States might have thrived in the Andes, but their southward spread was stopped by the intervening tropical climates. The mere 700 miles of north-south distance prevented Mexican corn, squash, and beans from reaching the U.S. Southwest for several thousand years after their domestication in Mexico, and Mexican chili peppers and chenopods never did reach it in prehistoric times. For thousands of years after corn was domesticated in Mexico, it failed to spread northward into eastern North America, because of the cooler climates and shorter growing season prevailing there. At some time between A.D. 1 and A.D. 200, corn finally appeared in the eastern United States but only as a very minor crop. Not until around A.D. 900, after hardy varieties of corn adapted to northern climates had been developed, could corn-based agriculture contribute to the flowering of the most complex Native American society of North America, the Mississippian culture—a brief flowering ended by European-introduced germs arriving with and after Columbus.

Recall that most Fertile Crescent crops prove, upon genetic study, to derive from only a single domestication process, whose resulting crop spread so quickly that it preempted any other incipient domestications of the same or related species. In contrast, many apparently widespread Native American crops prove to consist of related species or even of genetically distinct varieties of the same species, independently domesticated in Mesoamerica, South America, and the eastern United States. Closely related species replace each other geographically among the amaranths, beans, chenopods, chili peppers, cottons, squashes, and tobaccos. Different varieties of the same species replace each other among the kidney beans, lima beans, the chili pepper *Capsicum annuum / chinense*, and the squash *Cucurbita pepo*. Those legacies of multiple independent domestications may provide further testimony to the slow diffusion of crops along the Americas' north-south axis.

Africa and the Americas are thus the two largest landmasses with a predominantly north-south axis and resulting slow diffusion. In certain other parts of the world, slow north-south diffusion was important on a smaller scale. These other examples include the snail's pace of crop exchange between Pakistan's Indus Valley and South India, the slow spread of South Chinese food production into Peninsular Malaysia, and

the failure of tropical Indonesian and New Guinean food production to arrive in prehistoric times in the modern farmlands of southwestern and southeastern Australia, respectively. Those two corners of Australia are now the continent's breadbaskets, but they lie more than 2,000 miles south of the equator. Farming there had to await the arrival from faraway Europe, on European ships, of crops adapted to Europe's cool climate and short growing season.

I HAVE BEEN dwelling on latitude, readily assessed by a glance at a map, because it is a major determinant of climate, growing conditions, and ease of spread of food production. However, latitude is of course not the only such determinant, and it is not always true that adjacent places at the same latitude have the same climate (though they do necessarily have the same day length). Topographic and ecological barriers, much more pronounced on some continents than on others, were locally important obstacles to diffusion.

For instance, crop diffusion between the U.S. Southeast and Southwest was very slow and selective although these two regions are at the same latitude. That's because much of the intervening area of Texas and the southern Great Plains was dry and unsuitable for agriculture. A corresponding example within Eurasia involved the eastern limit of Fertile Crescent crops, which spread rapidly westward to the Atlantic Ocean and eastward to the Indus Valley without encountering a major barrier. However, farther eastward in India the shift from predominantly winter rainfall to predominantly summer rainfall contributed to a much more delayed extension of agriculture, involving different crops and farming techniques, into the Ganges plain of northeastern India. Still farther east, temperate areas of China were isolated from western Eurasian areas with similar climates by the combination of the Central Asian desert, Tibetan plateau, and Himalayas. The initial development of food production in China was therefore independent of that at the same latitude in the Fertile Crescent, and gave rise to entirely different crops. However, even those barriers between China and western Eurasia were at least partly overcome during the second millennium B.C., when West Asian wheat, barley, and horses reached China.

By the same token, the potency of a 2,000-mile north-south shift as a barrier also varies with local conditions. Fertile Crescent food production

spread southward over that distance to Ethiopia, and Bantu food production spread quickly from Africa's Great Lakes region south to Natal, because in both cases the intervening areas had similar rainfall regimes and were suitable for agriculture. In contrast, crop diffusion from India south to southwestern Australia was completely impossible, and diffusion over the much shorter distance from Mexico to the U.S. Southwest and Southeast was slow, because the intervening areas were deserts hostile to agriculture. The lack of a high-elevation plateau in Mesoamerica south of Guatemala, and Mesoamerica's extreme narrowness south of Mexico and especially in Panama, were at least as important as the latitudinal gradient in throttling crop and livestock exchanges between the highlands of Mexico and the Andes.

Continental differences in axis orientation affected the diffusion not only of food production but also of other technologies and inventions. For example, around 3,000 B.C. the invention of the wheel in or near Southwest Asia spread rapidly west and east across much of Eurasia within a few centuries, whereas the wheels invented independently in prehistoric Mexico never spread south to the Andes. Similarly, the principle of alphabetic writing, developed in the western part of the Fertile Crescent by 1500 B.C., spread west to Carthage and east to the Indian subcontinent within about a thousand years, but the Mesoamerican writing systems that flourished in prehistoric times for at least 2,000 years never reached the Andes.

Naturally, wheels and writing aren't directly linked to latitude and day length in the way crops are. Instead, the links are indirect, especially via food production systems and their consequences. The earliest wheels were parts of ox-drawn carts used to transport agricultural produce. Early writing was restricted to elites supported by food-producing peasants, and it served purposes of economically and socially complex food-producing societies (such as royal propaganda, goods inventories, and bureaucratic record keeping). In general, societies that engaged in intense exchanges of crops, livestock, and technologies related to food production were more likely to become involved in other exchanges as well.

America's patriotic song "America the Beautiful" invokes our spacious skies, our amber waves of grain, from sea to shining sea. Actually, that song reverses geographic realities. As in Africa, in the Americas the spread of native crops and domestic animals was slowed by constricted skies and environmental barriers. No waves of native grain ever stretched from the Atlantic to the Pacific coast of North America, from Canada to Patagonia,

or from Egypt to South Africa, while amber waves of wheat and barley came to stretch from the Atlantic to the Pacific across the spacious skies of Eurasia. That faster spread of Eurasian agriculture, compared with that of Native American and sub-Saharan African agriculture, played a role (as the next part of this book will show) in the more rapid diffusion of Eurasian writing, metallurgy, technology, and empires.

To bring up all those differences isn't to claim that widely distributed crops are admirable, or that they testify to the superior ingenuity of early Eurasian farmers. They reflect, instead, the orientation of Eurasia's axis compared with that of the Americas or Africa. Around those axes turned the fortunes of history.

# LETHAL GIFT OF LIVESTOCK

WE HAVE NOW TRACED HOW FOOD PRODUCTION AROSE in a few centers, and how it spread at unequal rates from there to other areas. Those geographic differences constitute important ultimate answers to Yali's question about why different peoples ended up with disparate degrees of power and affluence. However, food production itself is not a proximate cause. In a one-on-one fight, a naked farmer would have no advantage over a naked hunter-gatherer.

Instead, one part of the explanation for farmer power lies in the much denser populations that food production could support: ten naked farmers certainly would have an advantage over one naked hunter-gatherer in a fight. The other part is that neither farmers nor hunter-gatherers are naked, at least not figuratively. Farmers tend to breathe out nastier germs, to own better weapons and armor, to own more-powerful technology in general, and to live under centralized governments with literate elites better able to wage wars of conquest. Hence the next four chapters will explore how the ultimate cause of food production led to the proximate causes of germs, literacy, technology, and centralized government.

The links connecting livestock and crops to germs were unforgettably illustrated for me by a hospital case about which I learned through a physician friend. When my friend was an inexperienced young doctor, he was

called into a hospital room to deal with a married couple stressed-out by a mysterious illness. It did not help that the couple was also having difficulty communicating with each other, and with my friend. The husband was a small, timid man, sick with pneumonia caused by an unidentified microbe, and with only limited command of the English language. Acting as translator was his beautiful wife, worried about her husband's condition and frightened by the unfamiliar hospital environment. My friend was also stressed-out from a long week of hospital work, and from trying to figure out what unusual risk factors might have brought on the strange illness. The stress caused my friend to forget everything he had been taught about patient confidentiality: he committed the awful blunder of requesting the woman to ask her husband whether he'd had any sexual experiences that could have caused the infection.

As the doctor watched, the husband turned red, pulled himself together so that he seemed even smaller, tried to disappear under his bedsheets, and stammered out words in a barely audible voice. His wife suddenly screamed in rage and drew herself up to tower over him. Before the doctor could stop her, she grabbed a heavy metal bottle, slammed it with full force onto her husband's head, and stormed out of the room. It took a while for the doctor to revive her husband and even longer to elicit, through the man's broken English, what he'd said that so enraged his wife. The answer slowly emerged: he had confessed to repeated intercourse with sheep on a recent visit to the family farm; perhaps that was how he had contracted the mysterious microbe.

This incident sounds bizarrely one-of-a-kind and of no possible broader significance. In fact, it illustrates an enormous subject of great importance: human diseases of animal origins. Very few of us love sheep in the carnal sense that this patient did. But most of us platonically love our pet animals, such as our dogs and cats. As a society, we certainly appear to have an inordinate fondness for sheep and other livestock, to judge from the vast numbers of them that we keep. For example, at the time of a recent census, Australia's 17,085,400 people thought so highly of sheep that they kept 161,600,000 of them.

Some of us adults, and even more of our children, pick up infectious diseases from our pets. Usually they remain no more than a nuisance, but a few have evolved into something far more serious. The major killers of humanity throughout our recent history—smallpox, flu, tuberculosis, malaria, plague, measles, and cholera—are infectious diseases that evolved

from diseases of animals, even though most of the microbes responsible for our own epidemic illnesses are paradoxically now almost confined to humans. Because diseases have been the biggest killers of people, they have also been decisive shapers of history. Until World War II, more victims of war died of war-borne microbes than of battle wounds. All those military histories glorifying great generals oversimplify the ego-deflating truth: the winners of past wars were not always the armies with the best generals and weapons, but were often merely those bearing the nastiest germs to transmit to their enemies.

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 escalat-

ing 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.

**O**BVIOUSLY, 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 start-

ing 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 Foré 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 Cortés landed on the coast of Mexico with 600 Spaniards, to conquer the fiercely militaristic Aztec Empire with a population of many millions. That Cortés reached the Aztec capital of Tenochtitlán, 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 naïveté of the Aztecs. But when Cortés's next onslaught came, the Aztecs were no longer naïve 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 Cuitláhuac. 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 Chap-

ter 3, the result of the throne's being left vacant was that two other sons of Huayna Capac, Atahualpa 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 Tenochtitlán were among the world's most populous cities at the time. Why didn't Tenochtitlán 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.

## CHAPTER 12

# BLUEPRINTS AND BORROWED LETTERS

NINETEENTH-CENTURY AUTHORS TENDED TO INTERPRET history as a progression from savagery to civilization. Key hallmarks of this transition included the development of agriculture, metallurgy, complex technology, centralized government, and writing. Of these, writing was traditionally the one most restricted geographically: until the expansions of Islam and of colonial Europeans, it was absent from Australia, Pacific islands, subequatorial Africa, and the whole New World except for a small part of Mesoamerica. As a result of that confined distribution, peoples who pride themselves on being civilized have always viewed writing as the sharpest distinction raising them above "barbarians" or "savages."

Knowledge brings power. Hence writing brings power to modern societies, by making it possible to transmit knowledge with far greater accuracy and in far greater quantity and detail, from more distant lands and more remote times. Of course, some peoples (notably the Incas) managed to administer empires without writing, and "civilized" peoples don't always defeat "barbarians," as Roman armies facing the Huns learned. But the European conquests of the Americas, Siberia, and Australia illustrate the typical recent outcome.

Writing marched together with weapons, microbes, and centralized