GUNS, GERMS, AND STEEL

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PROLOGUE

YALI'S QUESTION

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

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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 invad-

ers. 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.

BEFORE 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.

DOES 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 considered 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 socie-

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ties 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 *dis*advantages under which most children in industrialized societies now grow up. Certainly, there is no hint at all of any intellectual *dis*advantage 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

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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 Yucatàn 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.

AUTHORS 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 view is not held in esteem by historians; it is considered wrong or simplistic, or it is caricatured as environmental determinism and dismissed, or else the whole subject of trying to understand worldwide differences is shelved as too difficult. Yet geography obviously has *some* effect on history; the open question concerns how much effect, and whether geography can account for history's broad pattern.

The time is now ripe for a fresh look at these questions, because of new information from scientific disciplines seemingly remote from human history. Those disciplines include, above all, genetics, molecular biology, and biogeography as applied to crops and their wild ancestors; the same disciplines plus behavioral ecology, as applied to domestic animals and their wild ancestors; molecular biology of human germs and related germs of animals; epidemiology of human diseases; human genetics; linguistics; archaeological studies on all continents and major islands; and studies of the histories of technology, writing, and political organization.

CHAPTER 3

COLLISION AT CAJAMARCA

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

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

The most dramatic moment in subsequent European-Native American

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

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

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

WHAT UNFOLDED THAT day at Cajamarca is well known, because it was recorded in writing by many of the Spanish participants. To get a flavor of those events, let us relive them by weaving together excerpts from

eyewitness accounts by six of Pizarro's companions, including his brothers Hernando and Pedro:

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

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

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

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

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

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

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

"First came a squadron of Indians dressed in clothes of different colors, like a

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

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

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

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

"The Friar returned to Pizarro, shouting, 'Come out! Come out, Christians! Come at these enemy dogs who reject the things of God. That tyrant has thrown my book of holy law to the ground! Did you not see what hap-

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pened? Why remain polite and servile toward this over-proud dog when the plains are full of Indians? March out against him, for I absolve you!'

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

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

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

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

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

LET US NOW trace the chain of causation in this extraordinary confrontation, beginning with the immediate events. When Pizarro and Atahuallpa

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

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

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

Today, it is hard for us to grasp the enormous numerical odds against which the Spaniards' military equipment prevailed. At the battle of Cajamarca recounted above, 168 Spaniards crushed a Native American army 500 times more numerous, killing thousands of natives while not losing a single Spaniard. Time and again, accounts of Pizarro's subsequent battles with the Incas, Cortés's conquest of the Aztecs, and other early European campaigns against Native Americans describe encounters in which a few dozen Euro-

European horsemen routed thousands of Indians with great slaughter. During Pizarro's march from Cajamarca to the Inca capital of Cuzco after Atahuallpa's death, there were four such battles: at Jauja, Vilcashuaman, Vilcaconga, and Cuzco. Those four battles involved a mere 80, 30, 110, and 40 Spanish horsemen, respectively, in each case ranged against thousands or tens of thousands of Indians.

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

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

In the Spanish conquest of the Incas, guns played only a minor role. The guns of those times (so-called harquebuses) were difficult to load and fire, and Pizarro had only a dozen of them. They did produce a big psychological effect on those occasions when they managed to fire. Far more important were the Spaniards' steel swords, lances, and daggers, strong sharp weapons that slaughtered thinly armored Indians. In contrast, Indian blunt clubs, while capable of battering and wounding Spaniards and their horses, rarely

succeeded in killing them. The Spaniards' steel or chain mail armor and, above all, their steel helmets usually provided an effective defense against club blows, while the Indians' quilted armor offered no protection against steel weapons.

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

The transformation of warfare by horses began with their domestication around 4000 B.C., in the steppes north of the Black Sea. Horses permitted people possessing them to cover far greater distances than was possible on foot, to attack by surprise, and to flee before a superior defending force could be gathered. Their role at Cajamarca thus exemplifies a military weapon that remained potent for 6,000 years, until the early 20th century, and that was eventually applied on all the continents. Not until the First World War did the military dominance of cavalry finally end. When we consider the advantages that

Spaniards derived from horses, steel weapons, and armor against foot soldiers without metal, it should no longer surprise us that Spaniards consistently won battles against enormous odds.

How did Atahuallpa come to be at Cajamarca? Atahuallpa and his army came to be at Cajamarca because they had just won decisive battles in a civil war that left the Incas divided and vulnerable. Pizarro quickly appreciated those divisions and exploited them. The reason for the civil war was that an epidemic of smallpox, spreading overland among South American Indians

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after its arrival with Spanish settlers in Panama and Colombia, had killed the Inca emperor Huayna Capac and most of his court around 1526, and then immediately killed his designated heir, Ninan Cuyuchi. Those deaths precipitated a contest for the throne between Atahuallpa and his half brother Huascar. If it had not been for the epidemic, the Spaniards would have faced a united empire.

Atahuallpa's presence at Cajamarca thus highlights one of the key factors in world history: diseases transmitted to peoples lacking immunity by invading peoples with considerable immunity. Smallpox, measles, influenza, typhus, bubonic plague, and other infectious diseases endemic in Europe played a decisive role in European conquests, by decimating many peoples on other continents. For example, a smallpox epidemic devastated the Aztecs after the failure of the first Spanish attack in 1520 and killed Cuitlahuac, the Aztec emperor who briefly succeeded Montezuma. Throughout the Americas, diseases introduced with Europeans spread from tribe to tribe far in advance of the Europeans themselves, killing an estimated 95 percent of the pre-Columbian Native American population. The most populous and highly organized native societies of North America, the Mississippian chiefdoms, disappeared in that way between 1492 and the late 1600s, even before Europeans themselves made their first settlement on the Mississippi River. A smallpox epidemic in 1713 was the biggest single step in the destruction of South Africa's native San people by European settlers. Soon after the British settlement of Sydney in 1788, the first of the epidemics that decimated Aboriginal Australians began. A well-documented example from Pacific islands is the epidemic that swept over Fiji in 1806, brought by a few European sailors who struggled ashore from the wreck of the ship *Argo*. Similar epidemics marked the histories of Tonga, Hawaii, and other Pacific islands.

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

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

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

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

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

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

In the New World the ability to write was confined to small elites among some peoples of modern Mexico and neighboring areas far to the north of the Inca Empire. Although the Spanish conquest of Panama, a mere 600 miles from the Incas' northern boundary, began already in 1510, no knowledge even of the Spaniards' existence appears to have reached the Incas until

Pizarro's first landing on the Peruvian coast in 1527. Atahuallpa remained entirely ignorant about Spain's conquests of Central America's most powerful and populous Indian societies.

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

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

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

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

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

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

CHAPTER 13

NECESSITY'S MOTHER

ON JULY 3, 1908, ARCHAEOLOGISTS EXCAVATING THE ancient Minoan palace at Phaistos, on the island of Crete, chanced upon one of the most remarkable objects in the history of technology. At first glance it seemed unprepossessing: just a small, flat, unpainted, circular disk of hard-baked clay, 6V2 inches in diameter. Closer examination showed each side to be covered with writing, resting on a curved line that spiraled clockwise in five coils from the disk's rim to its center. A total of 241 signs or letters was neatly divided by etched vertical lines into groups of several signs, possibly constituting words. The writer must have planned and executed the disk with care, so as to start writing at the rim and fill up all the available space along the spiraling line, yet not run out of space on reaching the center (page 230).

Ever since it was unearthed, the disk has posed a mystery for historians of writing. The number of distinct signs (45) suggests a syllabary rather than an alphabet, but it is still undeciphered, and the forms of the signs are unlike those of any other known writing system. Not another scrap of the strange script has turned up in the 89 years since its discovery. Thus, it remains unknown whether it represents an indigenous Cretan script or a foreign import to Crete.

For historians of technology, the Phaistos disk is even more baffling; its estimated date of 1700 B.C. makes it by far the earliest printed document in the

One side of the two-sided Phaistos Disk.
Credit: Heracleion Museum, Hellenic Republic Ministry of Culture.

world. Instead of being etched by hand, as were all texts of Crete's later Linear A and Linear B scripts, the disk's signs were punched into soft clay (subsequently baked hard) by stamps that bore a sign as raised type. The printer evidently had a set of at least 45 stamps, one for each sign appearing on the disk. Making these stamps must have entailed a great deal of work, and they surely weren't manufactured just to print this single document. Whoever used them was presumably doing a lot of writing. With those stamps, their owner could make copies much more quickly and neatly than if he or she had written out each of the script's complicated signs at each appearance.

The Phaistos disk anticipates humanity's next efforts at printing, which similarly used cut type or blocks but applied them to paper with ink, not to clay without ink. However, those next efforts did not appear until 2,500 years later in China and 3,100 years later in medieval Europe. Why was the disk's precocious technology not widely adopted in Crete or elsewhere in the ancient Mediterranean? Why was its printing method invented around 1700 B.C. in Crete and not at some other time in Mesopotamia, Mexico, or any other ancient center of writing? Why did it then take thousands of years to add the ideas of ink and a press and arrive at a printing press? The disk thus constitutes a threatening challenge to historians. If inventions are as idiosyncratic and unpredictable as the disk seems to suggest, then efforts to generalize about the history of technology may be doomed from the outset.

Technology, in the form of weapons and transport, provides the direct means by which certain peoples have expanded their realms and conquered other peoples. That makes it the leading cause of history's broadest pattern. But why were Eurasians, rather than Native Americans or sub- Saharan Africans, the ones to invent firearms, oceangoing ships, and steel equipment? The differences extend to most other significant technological advances, from printing presses to glass and steam engines. Why were all those inventions Eurasian? Why were all New Guineans and Native Australians in A.D. 1800 still using stone tools like ones discarded thousands of years ago in Eurasia and most of Africa, even though some of the world's richest copper and iron deposits are in New Guinea and Australia, respectively? All those facts explain why so many laypeople assume that Eurasians are superior to other peoples in inventiveness and intelligence.

If, on the other hand, no such difference in human neurobiology exists to account for continental differences in technological development, what does account for them? An alternative view rests on the heroic theory of invention. Technological advances seem to come disproportionately from a few very rare geniuses, such as Johannes Gutenberg, James Watt, Thomas Edison, and the Wright brothers. They were Europeans, or descendants of European emigrants to America. So were Archimedes and other rare geniuses of ancient times. Could such geniuses have equally well been born in Tasmania or Namibia? Does the history of technology depend on nothing more than accidents of the birthplaces of a few inventors?

Still another alternative view holds that it is a matter not of individual inventiveness but of the receptivity of whole societies to innovation. Some societies seem hopelessly conservative, inward looking, and hostile to change. That's the impression of many Westerners who have attempted to help Third World peoples and ended up discouraged. The people seem perfectly intelligent as individuals; the problem seems instead to lie with their societies. How else can one explain why the Aborigines of northeastern Aus-

tralia failed to adopt bows and arrows, which they saw being used by Torres Straits islanders with whom they traded? Might all the societies of an entire continent be unreceptive, thereby explaining technology's slow pace of development there? In this chapter we shall finally come to grips with a central problem of this book: the question of why technology did evolve at such different rates on different continents.

THE STARTING POINT for our discussion is the common view expressed in the saying "Necessity is the mother of invention." That is, inventions supposedly arise when a society has an unfulfilled need: some technology is widely recognized to be unsatisfactory or limiting. Would-be inventors, motivated by the prospect of money or fame, perceive the need and try to meet it. Some inventor finally comes up with a solution superior to the existing, unsatisfactory technology. Society adopts the solution if it is compatible with the society's values and other technologies.

Quite a few inventions do conform to this commonsense view of necessity as invention's mother. In 1942, in the middle of World War II, the U.S. government set up the Manhattan Project with the explicit goal of inventing the technology required to build an atomic bomb before Nazi Germany could do so. That project succeeded in three years, at a cost of $2 billion (equivalent to over $20 billion today). Other instances are Eli Whitney's 1794 invention of his cotton gin to replace laborious hand cleaning of cotton grown in the U.S. South, and James Watt's 1769 invention of his steam engine to solve the problem of pumping water out of British coal mines.

These familiar examples deceive us into assuming that other major inventions were also responses to perceived needs. In fact, many or most inventions were developed by people driven by curiosity or by a love of tinkering, in the absence of any initial demand for the product they had in mind. Once a device had been invented, the inventor then had to find an application for it. Only after it had been in use for a considerable time did consumers come to feel that they "needed" it. Still other devices, invented to serve one purpose, eventually found most of their use for other, unanticipated purposes. It may come as a surprise to learn that these inventions in search of a use include most of the major technological breakthroughs of modern times, ranging from the airplane and automobile, through the internal combustion engine and electric light bulb, to the phonograph and transistor. Thus, invention is often the mother of necessity, rather than vice versa.

A good example is the history of Thomas Edison's phonograph, the most original invention of the greatest inventor of modern times. When Edison built his first phonograph in 1877, he published an article proposing ten uses to which his invention might be put. They included preserving the last words of dying people, recording books for blind people to hear, announcing clock time, and teaching spelling. Reproduction of music was not high on Edison's list of priorities. A few years later Edison told his assistant that his invention had no commercial value. Within another few years he changed his mind and did enter business to sell phonographs—but for use as office dictating machines. When other entrepreneurs created jukeboxes by arranging for a phonograph to play popular music at the drop of a coin, Edison objected to this debasement, which apparently detracted from serious office use of his invention. Only after about 20 years did Edison reluctantly concede that the main use of his phonograph was to record and play music.

The motor vehicle is another invention whose uses seem obvious today. However, it was not invented in response to any demand. When Nikolaus Otto built his first gas engine, in 1866, horses had been supplying people's land transportation needs for nearly 6,000 years, supplemented increasingly by steam-powered railroads for several decades. There was no crisis in the availability of horses, no dissatisfaction with railroads.

Because Otto's engine was weak, heavy, and seven feet tall, it did not recommend itself over horses. Not until 1885 did engines improve to the point that Gottfried Daimler got around to installing one on a bicycle to create the first motorcycle; he waited until 1896 to build the first truck.

In 1905, motor vehicles were still expensive, unreliable toys for the rich. Public contentment with horses and railroads remained high until World War I, when the military concluded that it really did need trucks. Intensive postwar lobbying by truck manufacturers and armies finally convinced the public of its own needs and enabled trucks to begin to supplant horse-drawn wagons in industrialized countries. Even in the largest American cities, the changeover took 50 years.

Inventors often have to persist at their tinkering for a long time in the absence of public demand, because early models perform too poorly to be useful. The first cameras, typewriters, and television sets were as awful as Otto's seven-foot-tall gas engine. That makes it difficult for an inventor to foresee whether his or her awful prototype might eventually find a use and thus warrant more time and expense to develop it. Each year, the United States issues about 70,000 patents, only a few of which ultimately reach the

stage of commercial production. For each great invention that ultimately found a use, there are countless others that did not. Even inventions that meet the need for which they were initially designed may later prove more valuable at meeting unforeseen needs. While James Watt designed his steam engine to pump water from mines, it soon was supplying power to cotton mills, then (with much greater profit) propelling locomotives and boats.

THUS, THE COMMONSENSE view of invention that served as our starting point reverses the usual roles of invention and need. It also overstates the importance of rare geniuses, such as Watt and Edison. That "heroic theory of invention," as it is termed, is encouraged by patent law, because an applicant for a patent must prove the novelty of the invention submitted. Inventors thereby have a financial incentive to denigrate or ignore previous work. From a patent lawyer's perspective, the ideal invention is one that arises without any precursors, like Athene springing fully formed from the forehead of Zeus.

In reality, even for the most famous and apparently decisive modern inventions, neglected precursors lurked behind the bald claim "X invented Y." For instance, we are regularly told, "James Watt invented the steam engine in 1769," supposedly inspired by watching steam rise from a teakettle's spout. Unfortunately for this splendid fiction, Watt actually got the idea for his particular steam engine while repairing a model of Thomas Newcomen's steam engine, which Newcomen had invented 57 years earlier and of which over a hundred had been manufactured in England by the time of Watt's repair work.

Newcomen's engine, in turn, followed the steam engine that the Englishman Thomas Savery patented in 1698, which followed the steam engine that the Frenchman Denis Papin designed (but did not build) around 1680, which in turn had precursors in the ideas of the Dutch scientist Christiaan Huygens and others. All this is not to deny that Watt greatly improved Newcomen's engine (by incorporating a separate steam condenser and a double-acting cylinder), just as Newcomen had greatly improved Savery's.

Similar histories can be related for all modern inventions that are adequately documented. The hero customarily credited with the invention followed previous inventors who had had similar aims and had already produced designs, working models, or (as in the case of the Newcomen steam engine) commercially successful models. Edison's famous "invention" of the incandescent light bulb on the night of October 21, 1879, improved on many other incandescent light bulbs patented by other inventors between 1841 and

1878. Similarly, the Wright brothers' manned powered airplane was preceded by the manned unpowered gliders of Otto Lilienthal and the unmanned powered airplane of Samuel Langley; Samuel Morse's telegraph was preceded by those of Joseph Henry, William Cooke, and Charles Wheatstone; and Eli Whitney's gin for cleaning short-staple (inland) cotton extended gins that had been cleaning long-staple (Sea Island) cotton for thousands of years.

All this is not to deny that Watt, Edison, the Wright brothers, Morse, and Whitney made big improvements and thereby increased or inaugurated commercial success. The form of the invention eventually adopted might have been somewhat different without the recognized inventor's contribution. But the question for our purposes is whether the broad pattern of world history would have been altered significantly if some genius inventor had not been born at a particular place and time. The answer is clear: there has never been any such person. All recognized famous inventors had capable predecessors and successors and made their improvements at a time when society was capable of using their product. As we shall see, the tragedy of the hero who perfected the stamps used for the Phaistos disk was that he or she devised something that the society of the time could not exploit on a large scale.

MY EXAMPLES SO far have been drawn from modern technologies, because their histories are well known. My two main conclusions are that technology develops cumulatively, rather than in isolated heroic acts, and that it finds most of its uses after it has been invented, rather than being invented to meet a foreseen need. These conclusions surely apply with much greater force to the undocumented history of ancient technology. When Ice Age hunter-gatherers noticed burned sand and limestone residues in their hearths, it was impossible for them to foresee the long, serendipitous accumulation of discoveries that would lead to the first Roman glass windows (around A.D. 1), by way of the first objects with surface glazes (around 4000 B.C.), the first free-standing glass objects of Egypt and Mesopotamia (around 2500 B.C.), and the first glass vessels (around 1500 B.C.).

We know nothing about how those earliest known surface glazes themselves were developed. Nevertheless, we can infer the methods of prehistoric invention by watching technologically "primitive" people today, such as the New Guineans with whom I work. I already mentioned their knowledge of hundreds of local plant and animal species and each species' edibility, medical value, and other uses. New Guineans told me similarly about dozens

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of rock types in their environment and each type's hardness, color, behavior when struck or flaked, and uses. All of that knowledge is acquired by observation and by trial and error. I see that process of "invention" going on whenever I take New Guineans to work with me in an area away from their homes. They constantly pick up unfamiliar things in the forest, tinker with them, and occasionally find them useful enough to bring home. I see the same process when I am abandoning a campsite, and local people come to scavenge what is left. They play with my discarded objects and try to figure out whether they might be useful in New Guinea society. Discarded tin cans are easy: they end up reused as containers. Other objects are tested for purposes very different from the one for which they were manufactured. How would that yellow number 2 pencil look as an ornament, inserted through a pierced ear-lobe or nasal septum? Is that piece of broken glass sufficiently sharp and strong to be useful as a knife? Eureka!

The raw substances available to ancient peoples were natural materials such as stone, wood, bone, skins, fiber, clay, sand, limestone, and minerals, all existing in great variety. From those materials, people gradually learned to work particular types of stone, wood, and bone into tools; to convert particular clays into pottery and bricks; to convert certain mixtures of sand, limestone, and other "dirt" into glass; and to work available pure soft metals such as copper and gold, then to extract metals from ores, and finally to work hard metals such as bronze and iron.

A good illustration of the histories of trial and error involved is furnished by the development of gunpowder and gasoline from raw materials. Combustible natural products inevitably make themselves noticed, as when a resinous log explodes in a campfire. By 2000 B.C., Mesopotamians were extracting tons of petroleum by heating rock asphalt. Ancient Greeks discovered the uses of various mixtures of petroleum, pitch, resins, sulfur, and quicklime as incendiary weapons, delivered by catapults, arrows, firebombs, and ships. The expertise at distillation that medieval Islamic alchemists developed to produce alcohols and perfumes also let them distill petroleum into fractions, some of which proved to be even more powerful incendiaries. Delivered in grenades, rockets, and torpedoes, those incendiaries played a key role in Islam's eventual defeat of the Crusaders. By then, the Chinese had observed that a particular mixture of sulfur, charcoal, and saltpeter, which became known as gunpowder, was especially explosive. An Islamic chemical treatise of about A.D. 1100 describes seven gunpowder recipes, while a treatise from A.D. 1280 gives more than 70 recipes that had proved suitable for diverse purposes (one for rockets, another for cannons).

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As for postmedieval petroleum distillation, 19th-century chemists found the middle distillate fraction useful as fuel for oil lamps. The chemists discarded the most volatile fraction (gasoline) as an unfortunate waste product—until it was found to be an ideal fuel for internal-combustion engines. Who today remembers that gasoline, the fuel of modern civilization, originated as yet another invention in search of a use?

ONCE AN INVENTOR has discovered a use for a new technology, the next step is to persuade society to adopt it. Merely having a bigger, faster, more powerful device for doing something is no guarantee of ready acceptance. Innumerable such technologies were either not adopted at all or adopted only after prolonged resistance. Notorious examples include the U.S. Congress's rejection of funds to develop a supersonic transport in 1971, the world's continued rejection of an efficiently designed typewriter keyboard, and Britain's long reluctance to adopt electric lighting. What is it that promotes an invention's acceptance by a society?

Let's begin by comparing the acceptability of different inventions within the same society. It turns out that at least four factors influence acceptance. The first and most obvious factor is relative economic advantage compared with existing technology. While wheels are very useful in modern industrial societies, that has not been so in some other societies. Ancient Native Mexicans invented wheeled vehicles with axles for use as toys, but not for transport. That seems incredible to us, until we reflect that ancient Mexicans lacked domestic animals to hitch to their wheeled vehicles, which therefore offered no advantage over human porters.

A second consideration is social value and prestige, which can override economic benefit (or lack thereof). Millions of people today buy designer jeans for double the price of equally durable generic jeans —because the social cachet of the designer label counts for more than the extra cost. Similarly, Japan continues to use its horrendously cumbersome kanji writing system in preference to efficient alphabets or Japan's own efficient kana syllabary—because the prestige attached to kanji is so great.

Still another factor is compatibility with vested interests. This book, like probably every other typed document you have ever read, was typed with a QWERTY keyboard, named for the left-most six letters in its upper row. Unbelievable as it may now sound, that keyboard layout was designed in 1873 as a feat of anti-engineering. It employs a whole series of perverse tricks designed to force typists to type as slowly as possible, such as scattering the

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commonest letters over all keyboard rows and concentrating them on the left side (where right-handed people have to use their weaker hand). The reason behind all of those seemingly counterproductive features is that the typewriters of 1873 jammed if adjacent keys were struck in quick succession, so that manufacturers had to slow down typists. When improvements in typewriters eliminated the problem of jamming, trials in 1932 with an efficiently laid-out keyboard showed that it would let us double our typing speed and reduce our typing effort by 95 percent. But QWERTY keyboards were solidly entrenched by then. The vested interests of hundreds of millions of QWERTY typists, typing teachers, typewriter and computer salespeople, and manufacturers have crushed all moves toward keyboard efficiency for over 60-years.

While the story of the QWERTY keyboard may sound funny, many similar cases have involved much heavier economic consequences. Why does Japan now dominate the world market for transistorized electronic consumer products, to a degree that damages the United States's balance of payments with Japan, even though transistors were invented and patented in the United States? Because Sony bought transistor licensing rights from Western Electric at a time when the American electronics consumer industry was churning out vacuum tube models and reluctant to compete with its own products. Why were British cities still using gas street lighting into the 1920s, long after U.S. and German cities had converted to electric street lighting? Because British municipal governments had invested heavily in gas lighting and placed regulatory obstacles in the way of the competing electric light companies.

The remaining consideration affecting acceptance of new technologies is the ease with which their advantages can be observed. In A.D. 1340, when firearms had not yet reached most of Europe, England's earl of Derby and earl of Salisbury happened to be present in Spain at the battle of Tarifa, where Arabs used cannons against the Spaniards. Impressed by what they saw, the earls introduced cannons to the English army, which adopted them enthusiastically and already used them against French soldiers at the battle of Crécy six years later.

THUS, WHEELS, DESIGNER jeans, and QWERTY keyboards illustrate the varied reasons why the same
society is not equally receptive to all inventions. Conversely, the same invention's reception also varies greatly among contemporary societies. We are all familiar with the supposed generalization that rural Third World societies are less receptive to innovation than are

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Westernized industrial societies. Even within the industrialized world, some areas are much more receptive than others. Such differences, if they existed on a continental scale, might explain why technology developed faster on some continents than on others. For instance, if all Aboriginal Australian societies were for some reason uniformly resistant to change, that might account for their continued use of stone tools after metal tools had appeared on every other continent. How do differences in receptivity among societies arise?

A laundry list of at least 14 explanatory factors has been proposed by historians of technology. One is long life expectancy, which in principle should give prospective inventors the years necessary to accumulate technical knowledge, as well as the patience and security to embark on long development programs yielding delayed rewards. Hence the greatly increased life expectancy brought by modern medicine may have contributed to the recently accelerating pace of invention.

The next five factors involve economics or the organization of society: (1) The availability of cheap slave labor in classical times supposedly discouraged innovation then, whereas high wages or labor scarcity now stimulate the search for technological solutions. For example, the prospect of changed immigration policies that would cut off the supply of cheap Mexican seasonal labor to Californian farms was the immediate incentive for the development of a machine-harvestable variety of tomatoes in

California. (2) Patents and other property laws, protecting ownership rights of inventors, reward innovation in the modern West, while the lack of such protection discourages it in modern China. (3) Modern industrial societies provide extensive opportunities for technical training, as medieval Islam did and modern Zaire does not. (4) Modern capitalism is, and the ancient Roman economy was not, organized in a way that made it potentially rewarding to invest capital in technological development. (5) The strong individualism of U.S. society allows successful inventors to keep earnings for themselves, whereas strong family ties in New Guinea ensure that someone who begins to earn money will be joined by a dozen relatives expecting to move in and be fed and supported.

Another four suggested explanations are ideological, rather than economic or organizational: (1) Risk-taking behavior, essential for efforts at innovation, is more widespread in some societies than in others. (2) The scientific outlook is a unique feature of post-Renaissance European society that has contributed heavily to its modern technological preeminence. (3) Toler-

ance of diverse views and of heretics fosters innovation, whereas a strongly traditional outlook (as in China's emphasis on ancient Chinese classics) stifles it. (4) Religions vary greatly in their relation to technological innovation: some branches of Judaism and Christianity are claimed to be especially compatible with it, while some branches of Islam, Hinduism, and Brahmanism may be especially incompatible with it.

All ten of these hypotheses are plausible. But none of them has any necessary association with geography. If patent rights, capitalism, and certain religions do promote technology, what selected for those factors in postmedieval Europe but not in contemporary China or India?

At least the direction in which those ten factors influence technology seems clear. The remaining four proposed factors—war, centralized government, climate, and resource abundance—appear to act inconsistently: sometimes they stimulate technology, sometimes they inhibit it. (1) Throughout history, war has often been a leading stimulant of technological innovation. For instance, the enormous investments made in nuclear weapons during World War II and in airplanes and trucks during World War I launched whole new fields of technology. But wars can also deal devastating setbacks to technological development. (2) Strong centralized government boosted technology in late-19th-century Germany and Japan, and crushed it in China after A.D. 1500. (3) Many northern Europeans assume that technology thrives in a rigorous climate where survival is impossible without technology, and withers in a benign climate where clothing is unnecessary and bananas supposedly fall off the trees. An opposite view is that benign environments leave people free from the constant struggle for existence, free to devote themselves to innovation. (4) There has also been debate over whether technology is stimulated by abundance or by scarcity of environmental resources. Abundant resources might stimulate the development of inventions utilizing those resources, such as water mill technology in rainy northern Europe, with its many rivers—but why didn't water mill technology progress more rapidly in even rainier New Guinea? The destruction of Britain's forests has been suggested as the reason behind its early lead in developing coal technology, but why didn't deforestation have the same effect in China?

This discussion does not exhaust the list of reasons proposed to explain why societies differ in their receptivity to new technology. Worse yet, all of these proximate explanations bypass the question of the ultimate factors behind them. This may seem like a discouraging setback in our attempt to understand the course of history, since technology has undoubtedly been one

of history's strongest forces. However, I shall now argue that the diversity of independent factors behind technological innovation actually makes it easier, not harder, to understand history's broad pattern.

FO R THE PURPOSES of this book, the key question about the laundry list is whether such factors differed systematically from continent to continent and thereby led to continental differences in technological development. Most laypeople and many historians assume, expressly or tacitly, that the answer is yes. For example, it is widely believed that Australian Aborigines as a group shared ideological characteristics contributing to their technological backwardness: they were (or are) supposedly conservative, living in an imagined past Dreamtime of the world's creation, and not focused on practical ways to improve the present. A leading historian of Africa characterized Africans as inward looking and lacking Europeans' drive for expansion.

But all such claims are based on pure speculation. There has never been a study of many societies under similar socioeconomic conditions on each of two continents, demonstrating systematic ideological differences between the two continents' peoples. The usual reasoning is instead circular: because technological differences exist, the existence of corresponding ideological differences is inferred.

In reality, I regularly observe in New Guinea that native societies there differ greatly from each other in their prevalent outlooks. Just like industrialized Europe and America, traditional New Guinea has conservative societies that resist new ways, living side by side with innovative societies that selectively adopt new ways. The result, with the arrival of Western technology, is that the more entrepreneurial societies are now exploiting Western technology to overwhelm their conservative neighbors.

For example, when Europeans first reached the highlands of eastern New Guinea, in the 1930s, they "discovered" dozens of previously uncontacted Stone Age tribes, of which the Chimbu tribe proved especially aggressive in adopting Western technology. When Chimbus saw white settlers planting coffee, they began growing coffee themselves as a cash crop. In 1964 I met a 50-year-old Chimbu man, unable to read, wearing a traditional grass skirt, and born into a society still using stone tools, who had become rich by growing coffee, used his profits to buy a sawmill for $100,000 cash, and bought a fleet of trucks to transport his coffee and timber to market. In contrast, a neighboring highland people with whom I worked for eight years, the Daribi, are especially conservative and uninterested in new technology. When the first helicopter landed in the Daribi area, they briefly looked at it and just went back to what they had been doing; the Chimbus would have been bargaining to charter it. As a result, Chimbus are now moving into the Daribi area, taking it over for plantations, and reducing the Daribi to working for them.

On every other continent as well, certain native societies have proved very receptive, adopted foreign ways and technology selectively, and integrated them successfully into their own society. In Nigeria the Ibo people became the local entrepreneurial equivalent of New Guinea's Chimbus. Today the most numerous Native American tribe in the United States is the Navajo, who on European arrival were just one of several hundred tribes. But the Navajo proved especially resilient and able to deal selectively with innovation. They incorporated Western dyes into their weaving, became silversmiths and ranchers, and now drive trucks while continuing to live in traditional dwellings.

Among the supposedly conservative Aboriginal Australians as well, there are receptive societies along with conservative ones. At the one extreme, the Tasmanians continued to use stone tools superseded tens of thousands of years earlier in Europe and replaced in most of mainland Australia too. At the opposite extreme, some aboriginal fishing groups of southeastern Australia devised elaborate technologies for managing fish populations, including the construction of canals, weirs, and standing traps.

Thus, the development and reception of inventions vary enormously from society to society on the same continent. They also vary over time within the same society. Nowadays, Islamic societies in the Middle East are relatively conservative and not at the forefront of technology. But medieval Islam in the same region was technologically advanced and open to innovation. It achieved far higher literacy rates than contemporary Europe; it assimilated the legacy of classical Greek civilization to such a degree that many classical Greek books are now known to us only through Arabic copies; it invented or elaborated windmills, tidal mills, trigonometry, and lateen sails; it made major advances in metallurgy, mechanical and chemical engineering, and irrigation methods; and it adopted paper and gunpowder from China and transmitted them to Europe. In the Middle Ages the flow of technology was overwhelmingly from Islam to Europe, rather than from Europe to Islam as it is today. Only after around A.D. 1500 did the net direction of flow begin to reverse.

Innovation in China too fluctuated markedly with time. Until around A.D. 1450, China was technologically much more innovative and advanced

than Europe, even more so than medieval Islam. The long list of Chinese inventions includes canal lock gates, cast iron, deep drilling, efficient animal harnesses, gunpowder, kites, magnetic compasses, movable type, paper, porcelain, printing (except for the Phaistos disk), sternpost rudders, and wheelbarrows. China then ceased to be innovative for rea• sons about which we shall speculate in the Epilogue. Conversely, we think of western Europe and its derived North American societies as leading the modern world in technological innovation, but technology was less advanced in western Europe than in any other "civilized" area of the Old World until the late Middle Ages.

Thus, it is untrue that there are continents whose societies have tended to be innovative and continents whose societies have tended to be conservative. On any continent, at any given time, there are innovative societies and also conservative ones. In addition, receptivity to innovation fluctuates in time within the same region.

On reflection, these conclusions are precisely what one would expect if a society's innovativeness is determined by many independent factors. Without a detailed knowledge of all of those factors, innovativeness becomes unpredictable. Hence social scientists continue to debate the specific reasons why receptivity changed in Islam, China, and Europe, and why the Chimbus, Ibos, and Navajo were more receptive to new technology than were their neighbors. To the student of broad historical patterns, though, it makes no difference what the specific reasons were in each of those cases. The myriad factors affecting innovativeness make the historian's task paradoxically easier, by converting societal variation in innovativeness into essentially a random variable. That means that, over a large enough area (such as a whole continent) at any particular time, some proportion of societies is likely to be innovative.

WHERE DO INNOVATIONS actually come from? For all societies except the few past ones that were completely isolated, much or most new technology is not invented locally but is instead borrowed from other societies. The relative importance of local invention and of borrowing depends mainly on two factors: the ease of invention of the particular technology, and the proximity of the particular society to other societies.

Some inventions arose straightforwardly from a handling of natural raw materials. Such inventions developed on many independent occasions in world history, at different places and times. One example, which we have

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already considered at length, is plant domestication, with at least nine independent origins. Another is pottery, which may have arisen from observations of the behavior of clay, a very widespread natural material, when dried or heated. Pottery appeared in Japan around 14,000 years ago, in the Fertile Crescent and China by around 10,000 years ago, and in Amazonia, Africa's Sahel zone, the U.S. Southeast, and Mexico thereafter.

An example of a much more difficult invention is writing, which does not suggest itself by observation of any natural material. As we saw in Chapter 12, it had only a few independent origins, and the alphabet arose apparently only once in world history. Other difficult inventions include the water wheel, rotary quern, tooth gearing, magnetic compass, windmill, and camera obscura, all of which were invented only once or twice in the Old World and never in the New World.

Such complex inventions were usually acquired by borrowing, because they spread more rapidly than they could be independently invented locally. A clear example is the wheel, which is first attested around 3400 B.C. near the Black Sea, and then turns up within the next few centuries over much of Europe and Asia. All those early Old World wheels are of a peculiar design: a solid wooden circle constructed of three planks fastened together, rather than a rim with spokes. In contrast, the sole wheels of Native American societies (depicted on Mexican ceramic vessels) consisted of a single piece, suggesting a second independent invention of the wheel— as one would expect from other evidence for the isolation of New World from Old World civilizations.

No one thinks that that same peculiar Old World wheel design appeared repeatedly by chance at many separate sites of the Old World within a few centuries of each other, after 7 million years of wheelless human history. Instead, the utility of the wheel surely caused it to diffuse rapidly east and west over the Old World from its sole site of invention. Other examples of complex technologies that diffused east and west in the ancient Old World, from a single West Asian source, include door locks, pulleys, rotary querns, windmills—and the alphabet. A New World example of technological diffusion is metallurgy, which spread from the Andes via Panama to Mesoamerica.

When a widely useful invention does crop up in one society, it then tends to spread in either of two ways. One way is that other societies see or learn of the invention, are receptive to it, and adopt it. The second is that societies lacking the invention find themselves at a disadvantage vis-à-vis the inventing society, and they become overwhelmed and replaced if the disadvantage is sufficiently great. A simple example is the spread of muskets among New

Zealand's Maori tribes. One tribe, the Ngapuhi, adopted muskets from European traders around 1818. Over the course of the next 15 years, New Zealand was convulsed by the so-called Musket Wars, as musketless tribes either acquired muskets or were subjugated by tribes already armed with them. The outcome was that musket technology had spread throughout the whole of New Zealand by 1833: all surviving Maori tribes now had muskets.

When societies do adopt a new technology from the society that invented it, the diffusion may occur in many different contexts. They include peaceful trade (as in the spread of transistors from the United States to Japan in 1954), espionage (the smuggling of silkworms from Southeast Asia to the Mideast in A.D. 552), emigration (the spread of French glass and clothing manufacturing techniques over Europe by the 200,000 Huguenots expelled from France in 1685), and war. A crucial case of the last was the transfer of Chinese papermaking techniques to Islam, made possible when an Arab army defeated a Chinese army at the battle of Talas River in Central Asia in A.D. 751, found some papermakers among the prisoners of war, and brought them to Samarkand to set up paper manufacture.

In Chapter 12 we saw that cultural diffusion can involve either detailed "blueprints" or just vague ideas stimulating a reinvention of details. While Chapter 12 illustrated those alternatives for the spread of writing, they also apply to the diffusion of technology. The preceding paragraph gave examples of blueprint copying, whereas the transfer of Chinese porcelain technology to Europe provides an instance of long-drawn-out idea diffusion. Porcelain, a fine-grained translucent pottery, was invented in China around the 7th century A.D. When it began to reach Europe by the Silk Road in the 14th century (with no information about how it was manufactured), it was much admired, and many unsuccessful attempts were made to imitate it. Not until 1707 did the German alchemist Johann Bottger, after lengthy experiments with processes and with mixing various minerals and clays together, hit upon the solution and establish the now famous Meissen porcelain works. More or less independent later experiments in France and England led to Sèvres, Wedgwood, and Spode porcelains. Thus, European potters had to reinvent Chinese manufacturing methods for themselves, but they were stimulated to do so by having models of the desired product before them.

DEPENDING ON THEIR geographic location, societies differ in how readily they can receive technology by diffusion from other societies. The

most isolated people on Earth in recent history were the Aboriginal Tasmanians, living without oceangoing watercraft on an island 100 miles from Australia, itself the most isolated continent. The Tasmanians had no contact with other societies for 10,000 years and acquired no new technology other than what they invented themselves. Australians and New Guineans, separated from the Asian mainland by the Indonesian island chain, received only a trickle of inventions from Asia. The societies most accessible to receiving inventions by diffusion were those embedded in the major continents. In these societies technology developed most rapidly, because they accumulated not only their own inventions but also those of other societies. For example, medieval Islam, centrally located in Eurasia, acquired inventions from India and China and inherited ancient Greek learning.

The importance of diffusion, and of geographic location in making it possible, is strikingly illustrated by some otherwise incomprehensible cases of societies that abandoned powerful technologies. We tend to assume that useful technologies, once acquired, inevitably persist until superseded by better ones. In reality, technologies must be not only acquired but also maintained, and that too depends on many unpredictable factors. Any society goes through social movements or fads, in which economically useless things become valued or useful things devalued temporarily. Nowadays, when almost all societies on Earth are connected to each other, we cannot imagine a fad's going so far that an important technology would actually be discarded. A society that temporarily turned against a powerful technology would continue to see it being used by neighboring societies and would have the opportunity to reacquire it by diffusion (or would be conquered by neighbors if it failed to do so). But such fads can persist in isolated societies.

A famous example involves Japan's abandonment of guns. Firearms reached Japan in A.D. 1543, when two Portuguese adventurers armed with harquebuses (primitive guns) arrived on a Chinese cargo ship. The Japanese were so impressed by the new weapon that they commenced indigenous gun production, greatly improved gun technology, and by A.D. 1600 owned more and better guns than any other country in the world.

But there were also factors working against the acceptance of firearms in Japan. The country had a numerous warrior class, the samurai, for whom swords rated as class symbols and works of art (and as means for subjugating the lower classes). Japanese warfare had previously involved single combats between samurai swordsmen, who stood in the open, made ritual speeches, and then took pride in fighting gracefully. Such behavior became

lethal in the presence of peasant soldiers ungracefully blasting away with guns. In addition, guns were a foreign invention and grew to be despised, as did other things foreign in Japan after 1600. The samurai-controlled government began by restricting gun production to a few cities, then introduced a requirement of a government license for producing a gun, then issued licenses only for guns produced for the government, and finally reduced government orders for guns, until Japan was almost without functional guns again.

Contemporary European rulers also included some who despised guns and tried to restrict their availability. But such measures never got far in Europe, where any country that temporarily swore off firearms would be promptly overrun by gun-toting neighboring countries. Only because Japan was a populous, isolated island could it get away with its rejection of the powerful new military technology. Its safety in isolation came to an end in 1853, when the visit of Commodore Perry's U.S. fleet bristling with cannons convinced Japan of its need to resume gun manufacture.

That rejection and China's abandonment of oceangoing ships (as well as of mechanical clocks and water-driven spinning machines) are well-known historical instances of technological reversals in isolated or semi-isolated societies. Other such reversals occurred in prehistoric times. The extreme case is that of Aboriginal Tasmanians, who abandoned even bone tools and fishing to become the society with the simplest technology in the modern world (Chapter 15). Aboriginal Australians may have adopted and then abandoned bows and arrows. Torres Islanders abandoned canoes, while Gaua Islanders abandoned and then readopted them. Pottery was abandoned throughout Polynesia. Most Polynesians and many Melanesians abandoned the use of bows and arrows in war. Polar Eskimos lost the bow and arrow and the kayak, while Dorset Eskimos lost the bow and arrow, bow drill, and dogs.

These examples, at first so bizarre to us, illustrate well the roles of geography and of diffusion in the history of technology. Without diffusion, fewer technologies are acquired, and more existing technologies are lost.

BECAUSE TECHNOLOGY BEGETS more technology, the importance of an invention's diffusion potentially exceeds the importance of the original invention. Technology's history exemplifies what is termed an autocatalytic process: that is, one that speeds up at a rate that increases with time, because the process catalyzes itself. The explosion of technology since the Industrial Revolution impresses us today, but the medieval explosion was equally

impressive compared with that of the Bronze Age, which in turn dwarfed that of the Upper Paleolithic.

One reason why technology tends to catalyze itself is that advances depend upon previous mastery of simpler problems. For example, Stone Age farmers did not proceed directly to extracting and working iron, which requires high-temperature furnaces. Instead, iron ore metallurgy grew out of thousands of years of human experience with natural outcrops of pure metals soft enough to be hammered into shape without heat (copper and gold). It also grew out of thousands of years of development of simple furnaces to make pottery, and then to extract copper ores and work copper alloys (bronzes) that do not require as high temperatures as does iron. In both the Fertile Crescent and China, iron objects became common only after about 2,000 years of experience of bronze metallurgy. New World societies had just begun making bronze artifacts and had not yet started making iron ones at the time when the arrival of Europeans truncated the New World's independent trajectory.

The other main reason for autocatalysis is that new technologies and materials make it possible to generate still other new technologies by recombination. For instance, why did printing spread explosively in medieval Europe after Gutenberg printed his Bible in A.D. 1455, but not after that unknown printer printed the Phaistos disk in 1700 B.C.? The explanation is partly that medieval European printers were able to combine six technological advances, most of which were unavailable to the maker of the Phaistos disk. Of those advances—in paper, movable type, metallurgy, presses, inks, and scripts—paper and the idea of movable type reached Europe from China. Gutenberg's development of typecasting from metal dies, to overcome the potentially fatal problem of nonuniform type size, depended on many metallurgical developments: steel for letter punches, brass or bronze alloys (later replaced by steel) for dies, lead for molds, and a tin-zinc-lead alloy for type. Gutenberg's press was derived from screw presses in use for making wine and olive oil, while his ink was an oil-based improvement on existing inks. The alphabetic scripts that medieval Europe inherited from three millennia of alphabet development lent themselves to printing with movable type, because only a few dozen letter forms had to be cast, as opposed to the thousands of signs required for Chinese writing.

In all six respects, the maker of the Phaistos disk had access to much less powerful technologies to combine into a printing system than did Gutenberg. The disk's writing medium was clay, which is much bulkier and heavier than

paper. The metallurgical skills, inks, and presses of 1700 B.C. Crete were more primitive than those of A.D. 1455 Germany, so the disk had to be punched by hand rather than by cast movable type locked into a metal frame, inked, and pressed. The disk's script was a syllabary with more signs, of more complex form, than the Roman alphabet used by Gutenberg. As a result, the Phaistos disk's printing technology was much clumsier, and offered fewer advantages over writing by hand, than Gutenberg's printing press. In addition to all those technological drawbacks, the Phaistos disk was printed at a time when knowledge of writing was confined to a few palace or temple scribes. Hence there was little demand for the disk maker's beautiful product, and little incentive to invest in making the dozens of hand punches required. In contrast, the potential mass market for printing in medieval Europe induced numerous investors to lend money to Gutenberg.

HUMAN TECHNOLOGY DEVELOPED from the first stone tools, in use by two and a half million year
ago, to the 1996 laser printer that replaced my already outdated 1992 laser printer and that was used to print this book's manuscript. The rate of development was undetectably slow at the beginning, when hundreds of thousands of years passed with no discernible change in our stone tools and with no surviving evidence for artifacts made of other materials. Today, technology advances so rapidly that it is reported in the daily newspaper.

In this long history of accelerating development, one can single out two especially significant jumps. The first, occurring between 100,000 and 50,000 years ago, probably was made possible by genetic changes in our bodies: namely, by evolution of the modern anatomy permitting modern speech or modern brain function, or both. That jump led to bone tools, single-purpose stone tools, and compound tools. The second jump resulted from our adoption of a sedentary lifestyle, which happened at different times in different parts of the world, as early as 13,000 years ago in some areas and not even today in others. For the most part, that adoption was linked to our adoption of food production, which required us to remain close to our crops, orchards, and stored food surpluses.

Sedentary living was decisive for the history of technology, because it enabled people to accumulate nonportable possessions. Nomadic hunter-gatherers are limited to technology that can be carried.

local autonomy found in Europe. Second, the geography of China, unlike that of Europe, did not favor the prolonged survival of independent states. Instead, China's geography facilitated eventual conquest and unification over a vast area, followed by long periods of relative stability under imperial rule. The resulting state system suppressed most of the conditions required for the emergence of modern science. . . . The explanation outlined above is certainly oversimplified. However, one of the advantages of this kind of account is that it escapes the circularity which often creeps into explanations which do not go deeper than social or cultural differences between Europe and China. Such explanations can always be challenged with a further question: why were Europe and China different with regard to those social or cultural factors? Explanations rooted ultimately in geography and ecology, however, have reached bedrock."

It remains a challenge for historians to reconcile these different approaches to answering the question "Why Europe, not China." The answer may have important consequences for how best to govern China and Europe today. For example, from Lang's and my perspective, the disaster of China's Cultural Revolution of the 1960s and 1970s, when a few misguided leaders were able to close the school systems of the world's largest country for five years, may not be a unique one-time-only aberration, but may presage more such disasters in the future unless China can introduce far more decentralization into its political system. Conversely, Europe, in its rush toward political and economic unity today, will have to devote much thought to how to avoid dismantling the underlying reason behind its successes of the last five centuries.

THE THIRD RECENT Extension of *GGS*'s message to the modern world was to me the most unexpected
one. Soon after the book's publication, it was reviewed favorably by Bill Gates, and then I began receiving letters from other business people and economists who pointed out possible parallels between the histories of entire human societies discussed in *GGS* and the histories of groups in the business world. This correspondence concerned the following broad question: what is the best way to organize human groups, organizations, and businesses so as to maximize productivity, creativity, innovation, and wealth? Should your group have a centralized direction (in the extreme, a dictator), or should there be diffuse leadership or even anarchy? Should your collection of people be organized into a single group, or broken down into a small or large number of groups? Should you maintain open communication between your groups, or erect walls of secrecy between them? Should you

erect protectionist tariff walls against the outside, or should you expose your business to free competition?

These questions arise at many different levels and for many types of groups. They apply to the organization of entire countries: remember the perennial arguments about whether the best form of government is a benign dictatorship, a federal system, or an anarchical free-for-all. The same questions arise about the organization of different companies within the same industry. How can we account for the fact that Microsoft has been so successful recently, while IBM, which was formerly successful, fell behind but then drastically changed its organization and improved its success? How can we explain the different successes of different industrial belts? When I was a boy growing up in Boston, Route 128, the industrial belt around Boston, led the world in scientific creativity and imagination. But Route 128 has fallen behind, and now Silicon Valley is the center of innovation. The relations of businesses to one another in Silicon Valley and on Route 128 are very different, possibly resulting in those different outcomes.

Of course, there are also the famous differences between the productivities of the economies of whole countries, such as Japan, the United States, France, and Germany. Actually, though, there are big differences between the productivity and wealth of different business sectors even within the same country. For example, the Korean steel industry is equal in efficiency to ours, but all other Korean industries lag behind their American counterparts. What is it about the different organization of these various Korean industries that accounts for their differences in productivity within the same country?

Obviously, answers to these questions about differences in organizational success depend partly on the idiosyncrasies of individuals. For example, the success of Microsoft has surely had something to do with the personal talents of Bill Gates. Even with a superior corporate organization, Microsoft would not be successful with an ineffectual leader. Nevertheless, one can still ask: all other things being equal, or else in the long run, or else on the average, what form of organization of human groups is best?

My comparison of the histories of China, the Indian subcontinent, and Europe in the epilogue of *GGS* suggested an answer to this question as applied to technological innovation in whole countries. As explained in the preceding section, I inferred that competition between different political entities spurred innovation in geographically fragmented Europe, and that the lack of such competition held innovation back in unified China. Would that mean that a higher degree of political fragmentation than Europe's would be even

better? Probably not: India was geographically even more fragmented than Europe, but less innovative technologically. This suggested to me the Optimal Fragmentation Principle: innovation proceeds most rapidly in a society with some optimal intermediate degree of fragmentation: a too-unified society is at a disadvantage, and so is a too-fragmented society.

This inference rang a bell with Bill Lewis and other executives of McKinsey Global Institute, a leading consulting firm based in Washington, D.C., which carries out comparative studies of the economies of countries and industries all over the world. The executives were so struck by the parallels between their business experience and my historical inferences that they presented a copy of *GGS* to each of the firm's several hundred partners, and they presented me with copies of their reports on the economies of the United States, France, Germany, Korea, Japan, Brazil, and other countries. They, too, detected a key role of competition and group size in spurring innovation. Here are some of the conclusions that I gleaned from conversations with McKinsey executives and from their reports:

We Americans often fantasize that German and Japanese industries are super-efficient, exceeding American industries in productivity. In reality, that's not true: on the average across all industries, America's industrial productivity is higher than that in either Japan or Germany. But those average figures conceal big differences among the industries of each country, related to differences in organization—and those differences are very instructive. Let me give you two examples from McKinsey case studies on the German beer industry and the Japanese food-processing industry.

Germans make wonderful beer. Every time that my wife and I fly to Germany for a visit, we carry with us an empty suitcase, so we can fill it with bottles of German beer to bring back to the United States and enjoy over the following year. Yet the productivity of the German beer industry is only 43 percent that of the U.S. beer industry. Meanwhile, the German metalworking and steel industries are equal in productivity to their American counterparts. Since the Germans are evidently perfectly capable of organizing industries well, why can't they do so when it comes to beer?

It turns out that the German beer industry suffers from small-scale production. There are a thousand tiny beer companies in Germany, shielded from competition with one another because each German brewery has virtually a local monopoly, and they are also shielded from competition with imports. The

United States has 67 major beer breweries, producing 23 billion liters of beer per year. All of Germany's 1,000 breweries combined produce

only half as much. Thus the average U.S. brewery produces 31 times more beer than the average German brewery.

This fact results from local tastes and German government policies. German beer drinkers are fiercely loyal to their local brand, so there are no national brands in Germany analogous to our Budweiser, Miller, or Coors. Instead, most German beer is consumed within 30 miles of the factory where it is brewed. Therefore, the German beer industry cannot profit from economies of scale. In the beer business, as in other businesses, production costs decrease greatly with scale. The bigger the refrigerating unit for making beer, and the longer the assembly line for filling bottles with beer, the lower the cost of manufacturing beer. Those tiny German beer companies are relatively inefficient. There's no competition; there are just a thousand local monopolies.

The local beer loyalties of individual German drinkers are reinforced by German laws that make it hard for foreign beers to compete in the German market. The German government has so-called beer purity laws that specify exactly what can go into beer. Not surprisingly, those government purity specifications are based on what German breweries put into beer, and not on what American, French, and Swedish breweries like to put into beer. Because of those laws, not much foreign beer gets exported to Germany, and because of inefficiency and high prices much less of that wonderful German beer than you would otherwise expect gets sold abroad. (Before you object that German Löwenbräu beer is widely available in the United States, please read the label on the next bottle of Löwenbräu that you drink here: it's not produced in Germany but in North America, under license, in big factories with North American productivity and efficiencies of scale.)

The German soap industry and consumer electronics industry are similarly inefficient; their companies are not exposed to competition with one another, nor are they exposed to foreign competition, and so they do not acquire the best practices of international industry. (When is the last time that you bought an imported TV set made in Germany?) But those disadvantages are not shared by the German metal and steel industries, in which big German companies have to compete with one another and internationally, and thus are forced to acquire the best international practices.

My other favorite example from the McKinsey reports concerns the Japanese food-processing industry. We Americans tend to be paranoid about Japanese efficiency, and it is indeed formidable in some industries—but not in food-processing. The efficiency of the Japanese food-processing industry is a miserable 32 percent that of ours. There are 67,000 food-processing companies in Japan, compared to only 21,000 in the United States, which has twice Japan's population—so the average U.S. food-processing company is six times bigger than its Japanese counterpart. Why does the Japanese food-processing industry, like the German beer industry, consist of small companies with local monopolies? Basically, the answer is the same two reasons: local taste and government policies.

The Japanese are fanatics for fresh food. A container of milk in a U.S. supermarket bears only one date: the expiration date. When my wife and I visited a Tokyo supermarket with one of my wife's Japanese cousins, we were surprised to discover that in Japan a milk container bears three dates: the date the milk was manufactured, the date it arrived at the supermarket, and the expiration date. Milk production in Japan always starts at one minute past midnight, so that the milk that goes to market in the morning can be labeled as today's milk. If the milk were produced at 11:59 P.M., the date on the container would have to indicate that the milk was made yesterday, and no Japanese consumer would buy it.

As a result, Japanese food-processing companies enjoy local monopolies. A milk producer in northern Japan cannot hope to compete in southern Japan, because transporting milk there would take an extra day or two, a fatal disadvantage in the eyes of consumers. These local monopolies are reinforced by the Japanese government, which obstructs the import of foreign processed food by imposing a 10-day quarantine, among other restrictions. (Imagine how Japanese consumers who shun food labeled as only one day old feel about food 10 days old.) Hence Japanese food-producing companies are not exposed to either domestic or foreign competition, and they don't learn the best international methods for producing food. Partly as a result, food prices in Japan are very high: the best beef costs $200 a pound, while chicken costs $25 a pound.

Some other Japanese industries are organized very differently from the food processors. For instance, Japanese steel, metal, car, car parts, camera, and consumer electronic companies compete fiercely and have higher productivities than their U.S. counterparts. But the Japanese soap, beer, and computer industries, like the Japanese food-processing industry, are not exposed to competition, do not apply the best practices, and thus have lower productivities than the corresponding industries in the United States. (If you look around your house, you are likely to find that your TV set and camera, and possibly also your car, are Japanese, but that your computer and soap are not.)

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Finally, let's apply these lessons to comparing different industrial belts or businesses within the United States. Since the publication of *GGS*, I've spent much time talking with people from Silicon Valley and from Route 128, and they tell me that these two industrial belts are quite different in terms of corporate ethos. Silicon Valley consists of lots of companies that are fiercely competitive with one another. Nevertheless, there is much collaboration—a free flow of ideas, people, and information among companies. In contrast, I'm told, the businesses of Route 128 are much more secretive and insulated from one another, like Japanese milk-producing companies.

What about the contrast between Microsoft and IBM? Since *GGS* was published, I've acquired friends at Microsoft and have learned about that corporation's distinctive organization. Microsoft has lots of units, each comprised of 5 to 10 people, with free communication among units, and the units are not micromanaged; they are allowed a great deal of freedom in pursuing their own ideas. That unusual organization at Microsoft—which in essence is broken into many competing semi-independent units—contrasts with the organization at IBM, which until some years ago consisted of much more insulated groups and resulted in IBM's loss of competitive ability. Then IBM acquired a new chief executive officer who changed things drastically: IBM now has a more Microsoft-like organization, and I'm told that IBM's innovativeness has improved as a result.

All of this suggests that we may be able to extract a general principle about group organization. If your goal is innovation and competitive ability, you don't want either excessive unity or excessive fragmentation. Instead, you want your country, industry, industrial belt, or company to be broken up into groups that compete with one another while maintaining relatively free communication—like the U.S. federal government system, with its built-in competition between our 50 states.

THE REMAINING EXTENSION of *GGS* has been into one of the central questions of world economics:
why are some countries (like the United States and Switzerland) rich, while other countries (like Paraguay and Mali) are poor? Per-capita gross national products (GNP) of the world's richest countries are more than 100 times those of the poorest countries. This is not just a challenging theoretical question giving employment to economics professors, but also one with important policy implications. If we could identify the answers, then poor countries could concentrate on changing the things

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that keep them poor and on adopting the things that make other countries rich.

Obviously, part of the answer depends on differences in human institutions. The clearest evidence for this view comes from pairs of countries that divide essentially the same environment but have very different institutions and, associated with those institutions, different per-capita GNPs. Four flagrant examples are the comparison of South Korea with North Korea, the former West Germany with the former East Germany, the Dominican Republic with Haiti, and Israel with its Arab neighbors. Among the many "good institutions" often invoked to explain the greater wealth of the first-named country of each of these pairs are effective rule of law, enforcement of contracts, protection of private property rights, lack of corruption, low frequency of assassinations, openness to trade and to flow of capital, incentives for investment, and so on.

Undoubtedly, good institutions are indeed part of the answer to the different wealths of nations. Many, perhaps most, economists go further and believe that good institutions are overwhelmingly the most important explanation. Many governments, agencies, and foundations base their policies, foreign aid, and loans on this explanation, by making the development of good institutions in poor countries their top priority.

But there is increasing recognition that this good-institutions view is incomplete—not wrong, just incomplete—and that other important factors need addressing if poor countries are to become rich. This recognition has its own policy implications. One cannot just introduce good institutions to poor countries like Paraguay and Mali and expect those countries to adopt the institutions and achieve the per-capita GNPs of the United States and Switzerland. The criticisms of the good-institutions view are of two main types. One type recognizes the importance of other proximate variables besides good institutions, such as public health, soil- and climate-imposed limits on agricultural productivity, and environmental fragility. The other type concerns the origin of good institutions.

According to the latter criticism, it is not enough to consider good institutions as a proximate influence whose origins are of no further practical interest. Good institutions are not a random variable that could have popped up anywhere around the globe, in Denmark or in Somalia, with equal probability. Instead, it seems to me that, in the past, good institutions always arose because of a long chain of historical connections from ultimate causes rooted in geography to the proximate dependent variables of the institutions.

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We must understand that chain if we hope, now, to produce good institutions quickly in countries lacking them.

At the time that I wrote *GGS*, I commented, “The nations rising to new power [today] are still ones that were incorporated thousands of years ago into the old centers of dominance based on food production, or that have been repopulated by peoples from those centers. . . . The hand of history’s course at 8,000 B.C. lies heavily on us.” Two new papers by economists (Olsson and Hibbs, and Bockstette, Chanda, and Putterman) have subjected this postulated heavy hand of history to detailed tests. It turns out that countries in regions with long histories of state societies or agriculture have higher per-capita GNP than countries with short histories, even after other variables have been controlled. The effect explains a large fraction of the variance in GNP. Even just among countries with still-low or recently low GNPs, countries in regions with long histories of state societies or agriculture, like South Korea, Japan, and China, have higher growth rates than countries with short histories, such as New Guinea and the Philippines, even though some of the countries with short histories are much richer in natural resources.

There are many obvious reasons for these effects of history, such as that long experience of state societies and agriculture implies experienced administrators, experience with market economies, and so on. Statistically, part of that ultimate effect of history proves to be mediated by the familiar proximate causes of good institutions. But there is still a large effect of history remaining after one controls for the usual measures of good institutions. Hence there must be other mediating proximate mechanisms as well. Thus a key problem will be to understand the detailed chain of causation from a long history of state societies and agriculture to modern economic growth, in order to help developing countries advance up that chain more quickly. In short, the themes of *GGS* seem to me to be not only a driving force in the ancient world but also a ripe area for study in the modern world.