ALSO BY JARED DIAMOND

Guns, Germs, and Steel

Why Is Sex Fun?

The Third Chimpanzee

COLLAPSE

HOW SOCIETIES CHOOSE TO FAIL OR SUCCEED

JARED DIAMOND

VIKING

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To

Jack and Ann Hirschy,

Jill Hirschy Eliel and John Eliel,

Joyce Hirschy McDowell,

Dick (1929–2003) and Margy Hirschy,

and their fellow Montanans:

guardians of Montana's big sky

CHAPTER 4

The Ancient Ones: The Anasazi and Their Neighbors

Desert farmers ▪ Tree rings ▪ Agricultural strategies ▪ Chaco's problems and packrats ▪ Regional integration ▪ Chaco's decline and end ▪ Chaco's message ▪

Of the sites of societal collapses considered in this book, the most remote are Pitcairn and Henderson Islands discussed in the last chapter. At the opposite extreme, the ones closest to home for Americans are the Anasazi sites of Chaco Culture National Historical Park (Plates 9, 10) and Mesa Verde National Park, lying in the U.S. Southwest on New Mexico state highway 57 and near U.S. highway 666, respectively, less than 600 miles from my home in Los Angeles. Like the Maya cities that will be the subject of the next chapter, they and other ancient Native American ruins are popular tourist attractions that thousands of modern First World citizens visit each year. One of those former southwestern cultures, Mimbres, is also a favorite of art collectors because of its beautiful pottery decorated with geometrical patterns and realistic figures: a unique tradition created by a society numbering barely 4,000 people, and sustained at its peak for just a few generations before abruptly disappearing.

I concede that U.S. southwestern societies operated on a much smaller scale than did Maya cities, with populations of thousands rather than millions. As a result, Maya cities are far more extensive in area, have more lavish monuments and art, were products of more steeply stratified societies headed by kings, and possessed writing. But the Anasazi did manage to construct in stone the largest and tallest buildings erected in North America until the Chicago steel girder skyscrapers of the 1880s. Even though the Anasazi lacked a writing system such as the one that allows us to date Maya inscriptions to the exact day, we shall see that many U.S. southwestern structures can still be dated to within a year, thereby enabling archaeologists to understand the societies' history with much finer time resolution than is possible for Easter, Pitcairn, and Henderson Islands.

In the U.S. Southwest we are dealing with not just a single culture and collapse, but with a whole series of them (map, p. 142). Southwestern cultures that underwent regional collapses, drastic reorganizations, or abandonments at different locations and different times include Mimbres around A.D. 1130; Chaco Canyon, North Black Mesa, and the Virgin Anasazi in the middle or late 12th century; around 1300, Mesa Verde and the Kayenta Anasazi; Mogollon around 1400; and possibly as late as the 15th century, Hohokam, well known for its elaborate system of irrigation agriculture. While all of those sharp transitions occurred before Columbus's arrival in the New World in 1492, the Anasazi did not vanish as people: other southwestern Native American societies incorporating some of their descendants persist to this day, such as the Hopi and Zuni pueblos. What accounts for all those declines or abrupt changes in so many neighboring societies?

Favorite single-factor explanations invoke environmental damage, drought, or warfare and cannibalism. Actually, the field of U.S. southwestern prehistory is a graveyard for single-factor explanations. Multiple factors have operated, but they all go back to the fundamental problem that the U.S. Southwest is a fragile and marginal environment for agriculture—as is also much of the world today. It has low and unpredictable rainfall, quickly exhausted soils, and very low rates of forest regrowth. Environmental problems, especially major droughts and episodes of streambed erosion, tend to recur at intervals much longer than a human lifetime or oral memory span. Given those severe difficulties, it's impressive that Native Americans in the Southwest developed such complex farming societies as they did. Testimony to their success is that most of this area today supports a much sparser population growing their own food than it did in Anasazi times. It was a moving and unforgettable experience for me, while I was driving through areas of desert dotted with the remains of former Anasazi stone houses, dams, and irrigation systems, to see a now virtually empty landscape with just the occasional occupied house. The Anasazi collapse and other southwestern collapses offer us not only a gripping story but also an instructive one for the purposes of this book, illustrating well our themes of human environmental impact and climate change intersecting, environmental and population problems spilling over into warfare, the strengths but also the dangers of complex non-self-sufficient societies dependent on imports and exports, and societies collapsing swiftly after attaining peak population numbers and power.

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we thought might contribute to explaining those different outcomes of deforestation. Some trends immediately became obvious to us when we just eyeballed the data, but we ground the data through many statistical analyses in order to be able to put numbers on the trends.

What Affects Deforestation on Pacific Islands?

Deforestation is more severe on:

dry islands than wet islands;
cold high-latitude islands than warm equatorial islands;
old volcanic islands than young volcanic islands;
islands without aerial ash fallout than islands with it;
islands far from Central Asia's dust plume than islands near it;
islands without makatea than islands with it;
low islands than high islands;
remote islands than islands with near neighbors; and
small islands than big islands.

It turned out that all nine of the physical variables did contribute to the outcome (see the table above). Most important were variations in rainfall and latitude: dry islands, and cooler islands farther from the equator (at higher latitude), ended up more deforested than did wetter equatorial islands. That was as we had expected: the rate of plant growth and of seedling establishment increases with rainfall and with temperature. When one chops trees down in a wet hot place like the New Guinea lowlands, within a year new trees 20 feet tall have sprung up on the site, but tree growth is much slower in a cold dry desert. Hence regrowth can keep pace with moderate rates of cutting trees on wet hot islands, leaving the island in a steady state of being largely tree-covered.

Three other variables—island age, ash fallout, and dust fallout—had effects that we hadn't anticipated, because we hadn't been familiar with the scientific literature on the maintenance of soil fertility. Old islands that hadn't experienced any volcanic activity for over a million years ended up more deforested than young, recently active volcanic islands. That's because soil derived from fresh lava and ash contains nutrients that are necessary for plant growth, and that gradually become leached out by rain on older islands. One of the two main ways that those nutrients then become renewed on Pacific islands is by fallout of ash carried in the air from volcanic explosions. But the Pacific Ocean is divided by a line famous to geologists and known as the Andesite Line. In the Southwest Pacific on the Asian side of that line, volcanoes blow out ash that may be wind-carried for hundreds of miles and that maintains the fertility even of islands (like New Caledonia) that have no volcanoes of their own. In the central and eastern Pacific beyond the Andesite Line, the main aerial input of nutrients to renew soil fertility is instead in dust carried high in the atmosphere by winds from the steppes of Central Asia. Hence islands east of the Andesite Line, and far from Asia's dust plume, ended up more deforested than islands within the Andesite Line or nearer to Asia.

Another variable required consideration only for half a dozen islands that consist of the rock known as makatea—basically, a coral reef thrust into the air by geological uplift. The name arises from the Tuamotu island of Makatea, which consists largely of that rock. Makatea terrain is absolute hell to walk over; the deeply fissured, razor-sharp coral cuts one's boots, feet, and hands to shreds. When I first encountered makatea on Rennell Island in the Solomons, it took me 10 minutes to walk a hundred yards, and I was in constant terror of macerating my hands on a coral boulder if I touched it while thoughtlessly extending my hands to maintain my balance. Makatea can slice up stout modern boots within a few days of walking. While Pacific Islanders somehow managed to get around on it in bare feet, even they had problems. No one who has endured the agony of walking on makatea will be surprised that Pacific islands with makatea ended up less deforested than those without it.

That leaves three variables with more complex effects: elevation, distance, and area. High islands tended to become less deforested (even in their lowlands) than low islands, because mountains generate clouds and rain, which descends to the lowlands as streams stimulating lowland plant growth by their water, by their transport of eroded nutrients, and by transport of atmospheric dust. The mountains themselves may remain forest-covered if they are too high or too steep for gardening. Remote islands became more deforested than islands near neighbors—possibly because islanders were more likely to stay home and do things impacting their own environment than to spend time and energy visiting other islands to trade, raid, or settle. Big islands tended to become less deforested than small islands, for numerous reasons including lower perimeter/area ratios, hence fewer marine resources per person and lower population densities, more centuries required to chop down the forest, and more areas unsuitable for gardening remaining.

Our understanding of southwestern prehistory is detailed because of two advantages that archaeologists in this area enjoy. One is the packrat midden method that I'll discuss below, which provides us with a virtual time capsule of the plants growing within a few dozen yards of a midden within a few decades of a calculated date. That advantage has allowed paleobotanists to reconstruct changes in local vegetation. The other advantage allows archaeologists to date building sites to the nearest year by the tree rings of the site's wood construction beams, instead of having to rely on the radiocarbon method used by archaeologists elsewhere, with its inevitable errors of 50 to 100 years.

The tree ring method depends on the fact that rainfall and temperature vary seasonally in the Southwest, so that tree growth rates also vary seasonally, as true at other sites in the temperate zones as well. Hence temperate zone trees lay down new wood in annual growth rings, unlike tropical rainforest trees whose growth is more nearly continuous. But the Southwest is better for tree ring studies than most other temperate zone sites, because the dry climate results in excellent preservation of wooden beams from trees felled over a thousand years ago.

Here's how tree ring dating, known to scientists as *dendrochronology* (from the Greek roots *dendron* = tree, and *chronos* = time), works. If you cut down a tree today, it's straightforward to count the rings inwards, starting from the tree's outside (corresponding to this year's growth ring), and thereby to state that the 177th ring from the outermost one towards the center was laid down in the year 2005 minus 177, or 1828. But it's less straightforward to attach a date to a particular ring in an ancient Anasazi wooden beam, because at first you don't know in what year the beam was cut. However, the widths of tree growth rings vary from year to year, depending on rain or drought conditions in each year. Hence the sequence of rings in a tree cross-section is like a message in the Morse code formerly used for sending telegraph messages; dot-dot-dash-dot-dash in the Morse code, wide-wide-narrow-wide-narrow in a tree ring sequence. Actually, the ring sequence is even more diagnostic and richer in information than the Morse code, because trees actually contain rings spanning many different widths, rather than the Morse code's choice between only a dot or a dash.

Tree ring specialists (known as dendrochronologists) proceed by noting the sequence of wider and narrower rings in a tree cut down in a known recent year, and also noting the sequence in beams from trees cut down at various unknown times in the past. They then match up and align ring sequences with the same diagnostic wide/narrow patterns from different

beams. For instance, suppose that this year (2005) you cut down a tree that proves to be 400 years old (400 rings), and that has an especially distinctive sequence of five wide rings, two narrow rings, and six wide rings for the 13 years from 1643 back to 1631. If you find that same distinctive sequence starting seven years from the outermost ring in an old beam of unknown felling date with 332 rings, then you can conclude that the old beam came from a tree cut down in 1650 (seven years after 1643), and that the tree began to grow in the year 1318 (332 years before 1650). You then go on to align that beam, from the tree living between 1318 and 1650, with even older beams, and you similarly try to match up tree ring patterns and find a beam whose pattern shows that it comes from a tree that was cut down after 1318 but began growing before 1318, thereby extending your tree ring record farther back into the past. In that way, dendrochronologists have constructed tree ring records extending back for thousands of years in some parts of the world. Each such record is valid for a geographic area whose extent depends on local weather patterns, because weather and hence tree growth patterns vary with location. For instance, the basic tree ring chronology of the American Southwest applies (with some variation) to the area from northern Mexico to Wyoming.

A bonus of dendrochronology is that the width and substructure of each ring reflect the amount of rain and the season at which the rain fell during that particular year. Thus, tree ring studies also allow one to reconstruct past climate; e.g., a series of wide rings means a wet period, and a series of narrow rings means a drought. Tree rings thereby provide southwestern archaeologists with uniquely exact dating and uniquely detailed year-to-year environmental information.

The first humans to reach the Americas, living as hunter-gatherers, arrived in the U.S. Southwest by 11,000 B.C. but possibly earlier, as part of the colonization of the New World from Asia by peoples ancestral to modern Native Americans. Agriculture did not develop indigenously in the U.S. Southwest, because of a paucity of domesticable wild plant and animal species. Instead, it arrived from Mexico, where corn, squash, beans, and many other crops were domesticated—corn arriving by 2000 B.C., squash around 800 B.C., beans somewhat later, and cotton not until A.D. 400. People also kept domestic turkeys, about which there is some debate whether they were first domesticated in Mexico and spread to the Southwest, or vice versa, or whether they were domesticated independently in both areas. Originally, southwestern Native Americans just incorporated some agriculture as part of their hunter-gatherer lifestyle, as did the modern Apache in the 18th and 19th centuries: the Apache settled down to plant and harvest crops during the growing season, then moved around as hunter-gatherers during the rest of the year. By A.D. 1, some southwestern Native Americans had already taken up residence in villages and become primarily dependent on agriculture with ditch irrigation. Thereafter, their populations exploded in numbers and spread over the landscape until the retrenchments beginning around A.D. 1117.

At least three alternative types of agriculture emerged, all involving different solutions to the Southwest's fundamental problem: how to obtain enough water to grow crops in an environment most of which has rainfall so low and unpredictable that little or no farming is practiced there today. One of the three solutions consisted of so-called dryland agriculture, which meant relying on rainfall at the higher elevations where there really was enough rain to promote growth of crops in the fields on which the rain fell. A second solution did not depend on rain falling directly on the field, but instead was adopted in areas where the water table in the ground reached close enough to the surface that plant roots could extend down into the water table. That method was employed in canyon bottoms with intermittent or permanent streams and a shallow alluvial groundwater table, such as in Chaco Canyon. The third solution, practiced especially by the Hohokam and also at Chaco Canyon, consisted of collecting water runoff in ditches or canals to irrigate fields.

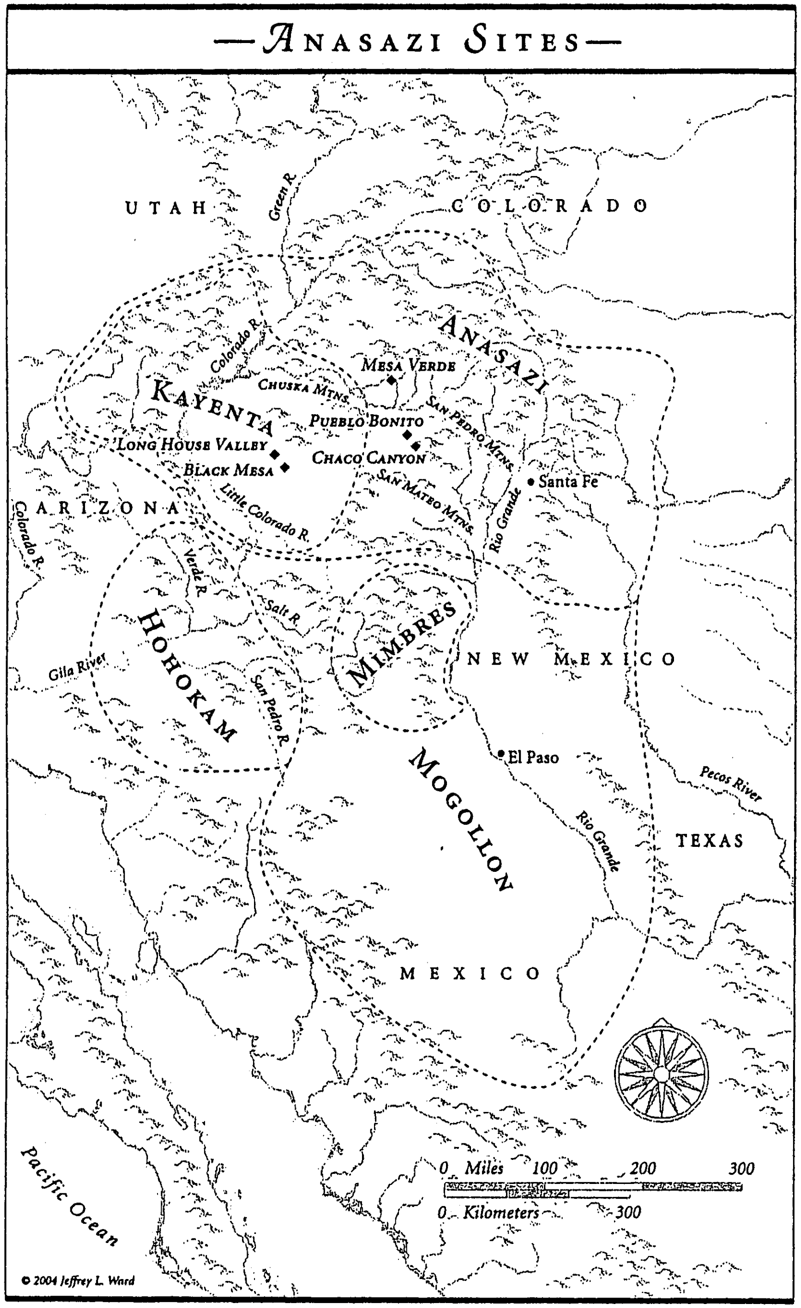
While the methods used in the Southwest to obtain enough water to grow crops were variants on those three types, people experimented in different locations with alternative strategies for applying those methods. The experiments lasted for almost a thousand years, and many of them succeeded for centuries, but eventually all except one succumbed to environmental problems caused by human impact or climate change. Each alternative involved different risks.

One strategy was to live at higher elevations where rainfall was higher, as did the Mogollon, the people at Mesa Verde, and the people of the early agricultural phase known as the Pueblo I phase. But that carried the risk that it is cooler at high than at low elevations, and in an especially cool year it might be too cold to grow crops at all. An opposite extreme was to farm at the warmer low elevations, but there the rainfall is insufficient for dryland agriculture. The Hohokam got around that problem by constructing the most extensive irrigation system in the Americas outside Peru, with hundreds of miles of secondary canals branching off a main canal 12 miles long, 16 feet deep, and 80 feet wide. But irrigation entailed the risk that human cutting of ditches and canals could lead to sudden heavy water runoff from rainstorms digging further down into the ditches and canals and incising deep channels called arroyos, in which the water level would drop below the field level, making irrigation impossible for people without pumps. Also, irrigation poses the danger that especially heavy rains or floods could wash away the dams and channels, as may indeed eventually have happened to the Hohokam.

Another, more conservative, strategy was to plant crops only in areas with reliable springs and groundwater tables. That was the solution initially adopted by the Mimbres, and by people in the farming phase known as Pueblo II at Chaco Canyon. However, it then became dangerously tempting to expand agriculture, in wet decades with favorable growing conditions, into marginal areas with less reliable springs or groundwater. The population multiplying in those marginal areas might then find itself unable to grow crops and starving when the unpredictable climate turned dry again. That fate actually befell the Mimbres, who started by safely farming the floodplain and then began to farm adjacent land above the floodplain as their population came to saturate the floodplain's capacity to support it. They got away with their gamble during a wet climate phase, when they were able to obtain half of their food requirements outside the floodplain. However, when drought conditions returned, that gamble left them with a population double what the floodplain could support, and Mimbres society collapsed suddenly under the stress.

Still another solution was to occupy an area for only a few decades, until the area's soil and game became exhausted, then to move on to another area. That method worked when people were living at low population densities, so that there were lots of unoccupied areas to which to move, and so that each occupied area could be left unoccupied again for sufficiently long after occupation that its vegetation and soil nutrients had time to recover. Most southwestern archaeological sites were indeed inhabited for only a few decades, even though our attention today is drawn to a few big sites that were inhabited continuously for several centuries, such as Pueblo Bonito in Chaco Canyon. However, the method of shifting sites after a short occupation became impossible at high population densities, when people filled up the whole landscape and there was nowhere left empty to move to.

One more strategy was to plant crops at many sites even though rainfall is locally unpredictable, and then to harvest crops at whichever sites did get



enough rain to produce a good harvest, and to redistribute some of that harvest to the people still living at all the sites that didn't happen to receive enough rain that year. That was one of the solutions eventually adopted at Chaco Canyon. But it involved the risk that redistribution required a complex political and social system to integrate activities between different sites, and that lots of people then ended up starving when that complex system collapsed.

The remaining strategy was to plant crops and live near permanent or dependable sources of water, but on landscape benches above the main floodways, so as to avoid the risk of a heavy flood washing out fields and villages; and to practice a diverse economy, exploiting ecologically diverse zones, so that each settlement would be self-sufficient. That solution, adopted by people whose descendants live today in the Southwest's Hopi and Zuni Pueblos, has succeeded for more than a thousand years. Some modern Hopis and Zunis, looking at the extravagance of American society around them, shake their heads and say, "We were here long before you came, and we expect still to be here long after you too are gone."

All of these alternative solutions face a similar overarching risk: that a series of good years, with adequate rainfall or with sufficiently shallow groundwater tables, may result in population growth, resulting in turn in society becoming increasingly complex and interdependent and no longer locally self-sufficient. Such a society then cannot cope with, and rebuild itself after, a series of bad years that a less populous, less interdependent, more self-sufficient society had previously been able to cope with. As we shall see, precisely that dilemma ended Anasazi settlement of Long House Valley, and perhaps other areas as well.

The most intensively studied abandonment was of the most spectacular and largest set of sites, the Anasazi sites in Chaco Canyon of northwestern New Mexico. Chaco Anasazi society flourished from about A.D. 600 for more than five centuries, until it disappeared some time between 1150 and 1200. It was a complexly organized, geographically extensive, regionally integrated society that erected the largest buildings in pre-Columbian North America. Even more than the barren treeless landscape of Easter Island, the barren treeless landscape of Chaco Canyon today, with its deep-cut arroyos and sparse low vegetation of salt-tolerant bushes, astonishes us, because the canyon is now completely uninhabited except for a few National Park Service rangers' houses. Why would anyone have built an advanced city in that wasteland, and why, having gone to all that work of building it, did they then abandon it?

When Native American farmers moved into the Chaco Canyon area around A.D. 600, they initially lived in underground pit houses, as did other contemporary Native Americans in the Southwest. Around A.D. 700 the Chaco Anasazi, out of contact with Native American societies building structures of stone a thousand miles to the south in Mexico, independently invented techniques of stone construction and eventually adopted rubble cores with veneers of cut stone facing (Plate 11). Initially, those structures were only one story high, but around A.D. 920 what eventually became the largest Chacoan site of Pueblo Bonito went up to two stories, then over the next two centuries rose to five or six stories with 600 rooms whose roof supports were logs up to 16 feet long and weighing up to 700 pounds.

Why, out of all the Anasazi sites, was it at Chaco Canyon that construction techniques and political and societal complexity reached their apogee? Likely reasons are some environmental advantages of Chaco Canyon, which initially represented a favorable environmental oasis within northwestern New Mexico. The narrow canyon caught rain runoff from many side-channels and a large upland area, which resulted in high alluvial groundwater levels permitting farming independent of local rainfall in some areas, and also high rates of soil renewal from the runoff. The large habitable area in the canyon and within 50 miles of it could support a relatively high population for such a dry environment. The Chaco region has a high diversity of useful wild plant and animal species, and a relatively low elevation that provides a long growing season for crops. At first, nearby pinyon and juniper woodlands provided the construction logs and firewood. The earliest roof beams identified by their tree rings, and still well preserved in the Southwest's dry climate, are of locally available pinyon pines, and firewood remains in early hearths are of locally available pinyon and juniper. Anasazi diets depended heavily on growing corn, plus some squash and beans, but early archaeological levels also show much consumption of wild plants such as pinyon nuts (75% protein), and much hunting of deer.

All those natural advantages of Chaco Canyon were balanced by two major disadvantages resulting from the Southwest's environmental fragility. One involved problems of water management. Initially, rain runoff would have been as a broad sheet over the flat canyon bottom, permitting floodplain agriculture watered both by the runoff and by the high alluvial groundwater table. When the Anasazi began diverting water into channels for irrigation, the concentration of water runoff in the channels and the clearing of vegetation for agriculture, combined with natural processes, resulted around A.D. 900 in the cutting of deep arroyos in which the water level was below field levels, thereby making irrigation agriculture and also agriculture based on groundwater impossible until the arroyos filled up again. Such arroyo-cutting can develop surprisingly suddenly. For example, at the Arizona city of Tucson in the late 1880s, American settlers excavated a so-called intercept ditch to intercept the shallow groundwater table and divert its water downstream onto the floodplain. Unfortunately, floods from heavy rains in the summer of 1890 cut into the head of that ditch, starting an arroyo that within a mere three days extended itself for a distance of six miles upstream, leaving an incised and agriculturally useless floodplain near Tucson. Early Southwest Native American societies probably attempted similar intercept ditches, with similar results. The Chaco Anasazi dealt with that problem of arroyos in the canyon in several ways: by building dams inside side-canyons above the elevation of the main canyon to store rainwater; by laying out field systems that that rainwater could irrigate; by storing rainwater coming down over the tops of the cliffs rimming the canyon's north wall between each pair of side-canyons; and by building a rock dam across the main canyon.

The other major environmental problem besides water management involved deforestation, as revealed by the method of packrat midden analysis. For those of you who (like me until some years ago) have never seen packrats, don't know what their middens are, and can't possibly imagine their relevance to Anasazi prehistory, here is a quick crash course in midden analysis. In 1849, hungry gold miners crossing the Nevada desert noticed some glistening balls of a candy-like substance on a cliff, licked or ate the balls, and discovered them to be sweet-tasting, but then they developed nausea. Eventually it was realized that the balls were hardened deposits made by small rodents, called packrats, that protect themselves by building nests of sticks, plant fragments, and mammal dung gathered in the vicinity, plus food remains, discarded bones, and their own feces. Not being toilet-trained, the rats urinate in their nests, and sugar and other substances crystallize from their urine as it dries out, cementing the midden to a brick-like consistency. In effect, the hungry gold miners were eating dried rat urine laced with rat feces and rat garbage.

Naturally, to save themselves work and to minimize their risk of being grabbed by a predator while out of the nest, packrats gather vegetation within just a few dozen yards of the nest. After a few decades the rats' progeny abandon their midden and move on to build a new nest, while the crystallized urine prevents the material in the old midden from decaying. By identifying the remains of the dozens of urine-encrusted plant species in a midden, paleobotanists can reconstruct a snapshot of the vegetation growing near the midden at the time that the rats were accumulating it, while zoologists can reconstruct something of the fauna from the insect and vertebrate remains. In effect, a packrat midden is a paleontologist's dream: a time capsule preserving a sample of the local vegetation, gathered within a few dozen yards of the spot within a period of a few decades, at a date fixed by radiocarbon-dating the midden.

In 1975 paleoecologist Julio Betancourt happened to visit Chaco Canyon while driving through New Mexico as a tourist. Looking down on the treeless landscape around Pueblo Bonito, he thought to himself, "This place looks like beat-up Mongolian steppe; where did those people get their timber and firewood?" Archaeologists studying the ruins had been asking themselves the same question. In a moment of inspiration three years later, when a friend asked him for completely unrelated reasons to write a grant proposal to study packrat middens, Julio recalled his first impression of Pueblo Bonito. A quick phone call to midden expert Tom Van Devender established that Tom had already collected a few middens at the National Park Service campground near Pueblo Bonito. Almost all of them had proved to contain needles of pinyon pines, which don't grow anywhere within miles today but which had nevertheless somehow furnished the roof beams for early phases of Pueblo Bonito's construction, as well as furnishing much of the charcoal found in hearths and trash middens. Julio and Tom realized that those must be old middens from a time when pines did grow nearby, but they had no idea how old: they thought perhaps just a century or so. Hence they submitted samples of those middens for radiocarbon dating. When the dates came back from the radiocarbon laboratory, Julio and Tom were astonished to learn that many of the middens were over a thousand years old.

That serendipitous observation triggered an explosion of packrat midden studies. Today we know that middens decay extremely slowly in the Southwest's dry climate. If protected from the elements under an overhang or inside a cave, middens can last 40,000 years, far longer than anyone would have dared to guess. As Julio showed me my first packrat midden near the Chaco Anasazi site of Kin Kletso, I stood in awe at the thought that that apparently fresh-looking nest might have been built at a time when mammoths, giant ground sloths, American lions, and other extinct Ice Age mammals were still living in the territory of the modern U.S.

In the Chaco Canyon area Julio went on to collect and radiocarbon-date 50 middens, whose dates turned out to encompass the entire period of the rise and fall of Anasazi civilization, from A.D. 600 to 1200. In this way Julio was able to reconstruct vegetational changes in Chaco Canyon throughout the history of Anasazi occupation. Those midden studies identified deforestation as the other one (besides water management) of the two major environmental problems caused by the growing population that had developed in Chaco Canyon by around A.D. 1000. Middens before that date still incorporated pinyon pine and juniper needles, like the first midden that Julio had analyzed, and like the midden that he showed me. Hence Chaco Anasazi settlements were initially constructed in a pinyon/juniper woodland unlike the present treeless landscape but convenient for obtaining firewood and construction timber nearby. However, middens dated after A.D. 1000 lacked pinyon and juniper, showing that the woodland had then become completely destroyed and the site had achieved its present treeless appearance. The reason why Chaco Canyon became deforested so quickly is the same as the reason that I discussed in Chapter 2 to explain why Easter Island and other dry Pacific islands settled by people were more likely to end up deforested than were wet islands: in a dry climate, the rate of tree regrowth on logged land may be too slow to keep up with the rate of logging.

The loss of the woodland not only eliminated pinyon nuts as a local food supply but also forced Chaco residents to find a different timber source for their construction needs, as shown by the complete disappearance of pinyon beams from Chaco architecture. Chacoans coped by going far afield to forests of ponderosa pine, spruce, and fir trees, growing in mountains up to 50 miles away at elevations several thousand feet higher than Chaco Canyon. With no draft animals available, about 200,000 logs weighing each up to 700 pounds were carried down the mountains and over that distance to Chaco Canyon by human muscle power alone.

A recent study by Julio's student Nathan English, working in collaboration with Julio, Jeff Dean, and Jay Quade, identified more exactly where the big spruce and fir logs came from. There are three potential sources of them in the Chaco area, growing at high elevations on three mountain ranges nearly equidistant from the canyon: the Chuska, San Mateo, and San Pedro Mountains. From which of those mountains did the Chaco Anasazi actually get their conifers? Trees from the three mountain ranges belong to the same species and look identical to each other. As a diagnostic signature, Nathan used isotopes of strontium, an element chemically very similar to calcium and hence incorporated along with calcium into plants and animals. Strontium exists as alternative forms (isotopes) differing slightly in atomic weight, of which strontium-87 and strontium-86 are commonest in nature. But the strontium-87/strontium 86 ratio varies with rock age and rock rubidium content, because strontium is produced by radioactive decay of a rubidium isotope. It turned out that living conifers from the three mountain ranges proved to be clearly separated by their strontium-87/strontium-86 ratios, with no overlap at all. From six Chaco ruins, Nathan sampled 52 conifer logs selected on the basis of their tree rings to have been felled at dates ranging from A.D. 974 to 1104. The result he obtained was that two-thirds of the logs could be traced by their strontium ratios to the Chuska Mountains, one-third to the San Mateo Mountains, and none at all to the San Pedro Mountains. In some cases a given Chaco building incorporated logs from both mountain ranges in the same year, or used logs from one mountain in one year and from the other mountain in another year, while the same mountain furnished logs to several different buildings in the same year. Thus, we have here unequivocal evidence of a well-organized, long-distance supply network for the Anasazi capital of Chaco Canyon.

Despite the development of these two environmental problems that reduced crop production and virtually eliminated timber supplies within Chaco Canyon itself, or because of the solutions that the Anasazi found to these problems, the canyon's population continued to increase, particularly during a big spurt of construction that began in A.D. 1029. Such spurts went on especially during wet decades, when more rain meant more food, more people, and more need for buildings. A dense population is attested not only by the famous Great Houses (such as Pueblo Bonito) spaced about a mile apart on the north side of Chaco Canyon, but also by holes drilled into the northern cliff face to support roof beams, indicating a continuous line of residences at the base of the cliffs between the Great Houses, and by the remains of hundreds of small settlements on the south side of the canyon. The size of the canyon's total population is unknown and much debated. Many archaeologists think that it was less than 5,000, and that those enormous buildings had few permanent occupants except priests and were just visited seasonally by peasants at the time of rituals. Other archaeologists note that Pueblo Bonito, which is just one of the large houses at Chaco Canyon, by itself was a building of 600 rooms, and that all those post holes suggest dwellings for much of the length of the canyon, thus implying a population much greater than 5,000. Such debates about estimated population sizes arise frequently in archaeology, as discussed for Easter Island and the Maya in other chapters of this book.

Whatever the number, this dense population could no longer support itself but was subsidized by outlying satellite settlements constructed in similar architectural styles and joined to Chaco Canyon by a radiating regional network of hundreds of miles of roads that are still visible today. Those outliers had dams to catch rain, which fell unpredictably and very patchily: a thunderstorm might produce abundant rain in one desert wash and no rain in another wash just a mile away. The dams meant that when a particular wash was fortunate enough to receive a rainstorm, much of the rainwater became stored behind the dam, and people living there could quickly plant crops, irrigate, and grow a huge surplus of food at that wash in that year. The surplus could then feed people living at all the other outliers that didn't happen to receive rain then.

Chaco Canyon became a black hole into which goods were imported but from which nothing tangible was exported. Into Chaco Canyon came: those tens of thousands of big trees for construction; pottery (all late-period pottery in Chaco Canyon was imported, probably because exhaustion of local firewood supplies precluded firing pots within the canyon itself); stone of good quality for making stone tools; turquoise for making ornaments, from other areas of New Mexico; and macaws, shell jewelry, and copper bells from the Hohokam and from Mexico, as luxury goods. Even food had to be imported, as shown by a recent study tracing the origins of corncobs excavated from Pueblo Bonito by means of the same strontium isotope method used by Nathan English to trace the origins of Pueblo Bonito's wooden beams. It turns out that, already in the 9th century, corn was being imported from the Chuska Mountains 50 miles to the west (also one of the two sources of roof beams), while a corncob from the last years of Pueblo Bonito in the 12th century came from the San Juan River system 60 miles to the north.

Chaco society turned into a mini-empire, divided between a well-fed elite living in luxury and a less well-fed peasantry doing the work and raising the food. The road system and the regional extent of standardized architecture testify to the large size of the area over which the economy and culture of Chaco and its outliers were regionally integrated. Styles of buildings indicate a three-step pecking order: the largest buildings, so-called Great Houses, in Chaco Canyon itself (residences of the governing chiefs?); outlier Great Houses beyond the canyon ("provincial capitals" of junior chiefs?); and small homesteads of just a few rooms (peasants' houses?).

Compared to smaller buildings, the Great Houses were distinguished by finer construction with veneer masonry, large structures called Great Kivas used for religious rituals (similar to ones still used today in modern Pueblos), and a higher ratio of storage space to total space. Great Houses far exceeded homesteads in their contents of imported luxury goods, such as the turquoise, macaws, shell jewelry, and copper bells mentioned above, plus imported Mimbres and Hohokam pottery. The highest concentration of luxury items located to date comes from Pueblo Bonito's room number 33, which held burials of 14 individuals accompanied by 56,000 pieces of turquoise and thousands of shell decorations, including one necklace of 2,000 turquoise beads and a basket covered with a turquoise mosaic and filled with turquoise and shell beads. As for evidence that the chiefs ate better than did the peasants, garbage excavated near Great Houses contained a higher proportion of deer and antelope bones than did garbage from homesteads, with the result that human burials indicate taller, better-nourished, less anemic people and lower infant mortality at Great Houses.

Why would outlying settlements have supported the Chaco center, dutifully delivering timber, pottery, stone, turquoise, and food without receiving anything material in return? The answer is probably the same as the reason why outlying areas of Italy and Britain today support our cities such as Rome and London, which also produce no timber or food but serve as political and religious centers. Like the modern Italians and British, Chacoans were now irreversibly committed to living in a complex, interdependent society. They could no longer revert to their original condition of self-supporting mobile little groups, because the trees in the canyon were gone, the arroyos were cut below field levels, and the growing population had filled up the region and left no unoccupied suitable areas to which to move. When the pinyon and juniper trees were cut down, the nutrients in the litter underneath the trees were flushed out. Today, more than 800 years later, there is still no pinyon/juniper woodland growing anywhere near the packrat middens containing twigs of the woodland that had grown there before A.D. 1000. Food remains in rubbish at archaeological sites attest to the growing problems of the canyon's inhabitants in nourishing themselves: deer declined in their diets, to be replaced by smaller game, especially rabbits and mice. Remains of complete headless mice in human coprolites (preserved dry feces) suggest that people were catching mice in the fields, beheading them, and popping them in whole.

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The last identified construction at Pueblo Bonito, dating from the decade after 1110, was from a wall of rooms enclosing the south side of the plaza, which had formerly been open to the outside. That suggests strife: people were evidently now visiting Pueblo Bonito not just to participate in its religious ceremonies and to receive orders, but also to make trouble. The last tree-ring-dated roof beam at Pueblo Bonito and at the nearby Great House of Chetro Ketl was cut in A.D. 1117, and the last beam anywhere in Chaco Canyon in A.D. 1170. Other Anasazi sites show more abundant evidence of strife, including signs of cannibalism, plus Kayenta Anasazi settlements at the tops of steep cliffs far from fields and water and understandable only as easily defended locations. At those southwestern sites that outlasted Chaco and survived until after A.D. 1250, warfare evidently became intense, as reflected in a proliferation of defensive walls and moats and towers, clustering of scattered small hamlets into larger hilltop fortresses, apparently deliberately burned villages containing unburied bodies, skulls with cut marks caused by scalping, and skeletons with arrowheads inside the body cavity. That explosion of environmental and population problems in the form of civil unrest and warfare is a frequent theme in this book, both for past societies (the Easter Islanders, Mangarevans, Maya, and Tikopians) and for modern societies (Rwanda, Haiti, and others).

The signs of warfare-related cannibalism among the Anasazi are an interesting story in themselves. While everyone acknowledges that cannibalism may be practiced in emergencies by desperate people, such as the Donner Party trapped by snow at Donner Pass en route to California in the winter of 1846–47, or by starving Russians during the siege of Leningrad during World War II, the existence of non-emergency cannibalism is controversial. In fact, it was reported in hundreds of non-European societies at the times when they were first contacted by Europeans within recent centuries. The practice took two forms: eating either the bodies of enemies killed in war, or else eating one's own relatives who had died of natural causes. New Guineans with whom I have worked over the past 40 years have matter-of-factly described their cannibalistic practices, have expressed disgust at our own Western burial customs of burying relatives without doing them the honor of eating them, and one of my best New Guinean workers quit his job with me in 1965 in order to partake in the consumption of his recently deceased prospective son-in-law. There have also been many archaeological finds of ancient human bones in contexts suggestive of cannibalism.

Nevetheless, many or most European and American anthropologists, brought up to regard cannibalism with horror in their own societies, are also horrified at the thought of it being practiced by peoples that they admire and study, and so they deny its occurrence and consider claims of it as racist slander. They dismiss all the descriptions of cannibalism by non-European peoples themselves or by early European explorers as unreliable hearsay, and they would evidently be convinced only by a videotape taken by a government official or, most convincing of all, by an anthropologist. However, no such tape exists, for the obvious reason that the first Europeans to encounter people reported to be cannibals routinely expressed their disgust at the practice and threatened its practitioners with arrest.

Such objections have created controversy around the many reports of human remains, with evidence consistent with cannibalism, found at Anasazi sites. The strongest evidence comes from an Anasazi site at which a house and its contents had been smashed, and the scattered bones of seven people were left inside the house, consistent with their having been killed in a war raid rather than properly buried. Some of the bones had been cracked in the same way that bones of animals consumed for food were cracked to extract the marrow. Other bones showed smooth ends, a hallmark of animal bones boiled in pots, but not of ones not boiled in pots. Broken pots themselves from that Anasazi site had residues of the human muscle protein myoglobin on the pots' inside, consistent with human flesh having been cooked in the pots. But skeptics might still object that boiling human meat in pots, and cracking open human bones, does not prove that other humans actually consumed the meat of the former owners of those bones (though why else would they go to all that trouble of boiling and cracking bones to be left scattered on the floor?). The most direct sign of cannibalism at the site is that dried human feces, found in the house's hearth and still well preserved after nearly a thousand years in that dry climate, proved to contain human muscle protein, which is absent from normal human feces, even from the feces of people with injured and bleeding intestines. This makes it probable that whoever attacked that site, killed the inhabitants, cracked open their bones, boiled their flesh in pots, scattered the bones, and relieved himself or herself by depositing feces in that hearth had actually consumed the flesh of his or her victims.

The final blow for Chacoans was a drought that tree rings show to have begun around A.D. 1130. There had been similar droughts previously, around A.D. 1090 and 1040, but the difference this time was that Chaco Canyon now held more people, more dependent on outlying settlements, and with no land left unoccupied. A drought would have caused the groundwater table to drop below the level where it could be tapped by plant roots and could support agriculture; a drought would also make rainfall-supported dryland agriculture and irrigation agriculture impossible. A drought that lasted more than three years would have been fatal, because modern Puebloans can store corn for only two or three years, after which it is too rotten or infested to eat. Probably the outlying settlements that had formerly supplied the Chaco political and religious centers with food lost faith in the Chacoan priests whose prayers for rain remained unanswered, and they refused to make more food deliveries. A model for the end of Anasazi settlement at Chaco Canyon, which Europeans did not observe, is what happened in the Pueblo Indian revolt of 1680 against the Spaniards, a revolt that Europeans did observe. As in Chaco Anasazi centers, the Spaniards had extracted food from local farmers by taxing them, and those food taxes were tolerated until a drought left the farmers themselves short of food, provoking them to revolt.

Some time between A.D. 1150 and 1200, Chaco Canyon was virtually abandoned and remained largely empty until Navajo sheepherders reoccupied it 600 years later. Because the Navajo did not know who had built the great ruins that they found there, they referred to those vanished former inhabitants as the Anasazi, meaning "the Ancient Ones." What actually happened to the thousands of Chacoan inhabitants? By analogy with historically witnessed abandonments of other pueblos during a drought in the 1670s, probably many people starved to death, some people killed each other, and the survivors fled to other settled areas in the Southwest. It must have been a planned evacuation, because most rooms at Anasazi sites lack the pottery and other useful objects that people would be expected to take with them in a planned evacuation, in contrast to the pottery still in the rooms of the above-mentioned site whose unfortunate occupants were killed and eaten. The settlements to which Chaco survivors managed to flee include some pueblos in the area of the modern Zuni pueblos, where rooms built in a style similar to Chaco Canyon houses and containing Chaco styles of pottery have been found at dates around the time of Chaco's abandonment.

Jeff Dean and his colleagues Rob Axtell, Josh Epstein, George Gumerman, Steve McCarroll, Miles Parker, and Alan Swedlund have carried out an especially detailed reconstruction of what happened to a group of about a thousand Kayenta Anasazi in Long House Valley in northeastern Arizona. They calculated the valley's actual population at various times from

A.D. 800 to 1350, based on numbers of house sites containing pottery that changed in style with time, thereby permitting dating of the house sites. They also calculated the valley's annual corn harvests as a function of time, from annual tree rings that provide a measure of rainfall, and from soil studies that provide information about the rise and fall of groundwater levels. It turned out that the rises and falls of the actual population after A.D. 800 closely mirrored the rises and falls of calculated annual corn harvests, except that the Anasazi completely abandoned the valley by A.D. 1300, at a time when some reduced corn harvests sufficient to support one-third of the valley's peak population (400 out of the peak of 1,070 people) could still have been extracted.

Why did those last 400 Kayenta Anasazi of Long House Valley not remain when most of their relatives were leaving? Perhaps the valley in A.D. 1300 had deteriorated for human occupation in other ways besides its reduced agricultural potential calculated in the authors' model. For instance, perhaps soil fertility had been exhausted, or else the former forests may have been felled, leaving no nearby timber for buildings and firewood, as we know to have been the case in Chaco Canyon. Alternatively, perhaps the explanation was that complex human societies require a certain minimum population size to maintain institutions that its citizens consider to be essential. How many New Yorkers would choose to remain in New York City if two-thirds of their family and friends had just starved to death there or fled, if the subway trains and taxis were no longer running, and if offices and stores had closed?

Along with those Chaco Canyon Anasazi and Long House Valley Anasazi whose fates we have followed, I mentioned at the start of this chapter that many other southwestern societies—the Mimbres, Mesa Verdeans, Hohokam, Mogollon, and others—also underwent collapses, reorganizations, or abandonments at various times within the period A.D. 1100–1500. It turns out that quite a few different environmental problems and cultural responses contributed to these collapses and transitions, and that different factors operated in different areas. For example, deforestation was a problem for the Anasazi, who required trees to supply the roof beams of their houses, but it wasn't as much of a problem for the Hohokam, who did not use beams in their houses. Salinization resulting from irrigation agriculture hurt the Hohokam, who had to irrigate their fields, but not the Mesa Verdeans, who did not have to irrigate. Cold affected the Mogollon and

Mesa Verdeans, living at high altitudes and at temperatures somewhat marginal for agriculture. Other southwestern peoples were done in by dropping water tables (e.g., the Anasazi) or by soil nutrient exhaustion (possibly the Mogollon). Arroyo cutting was a problem for the Chaco Anasazi, but not for the Mesa Verdeans.

Despite these varying proximate causes of abandonments, all were ultimately due to the same fundamental challenge: people living in fragile and difficult environments, adopting solutions that were brilliantly successful and understandable "in the short run," but that failed or else created fatal problems in the long run, when people became confronted with external environmental changes or human-caused environmental changes that societies without written histories and without archaeologists could not have anticipated. I put "in the short run" in quotation marks, because the Anasazi did survive in Chaco Canyon for about 600 years, considerably longer than the duration of European occupation anywhere in the New World since Columbus's arrival in A.D. 1492. During their existence, those various southwestern Native Americans experimented with half-a-dozen alternative types of economies (pp. 140–143). It took many centuries to discover that, among those economies, only the Pueblo economy was sustainable "in the long run," i.e., for at least a thousand years. That should make us modern Americans hesitate to be too confident yet about the sustainability of our First World economy, especially when we reflect how quickly Chaco society collapsed after its peak in the decade A.D. 1110–1120, and how implausible the risk of collapse would have seemed to Chacoans of that decade.

Within our five-factor framework for understanding societal collapses, four of those factors played a role in the Anasazi collapse. There were indeed human environmental impacts of several types, especially deforestation and arroyo cutting. There was also climate change in rainfall and temperature, and its effects interacted with the effects of human environmental impacts. Internal trade with friendly trade partners did play a crucial role in the collapse: different Anasazi groups supplied food, timber, pottery, stone, and luxury goods to each other, supporting each other in an interdependent complex society, but putting the whole society at risk of collapsing. Religious and political factors apparently played an essential role in sustaining the complex society, by coordinating the exchanges of materials, and by motivating people in outlying areas to supply food, timber, and pottery to the political and religious centers. The only factor in our five-factor list for whose operation there is not convincing evidence in the case of the Anasazi collapse is external enemies. While the Anasazi did indeed attack each other as their population grew and as the climate deteriorated, the civilizations of the U.S. Southwest were too distant from other populous societies to have been seriously threatened by any external enemies.

From that perspective, we can propose a simple answer to the long-standing either/or debate: was Chaco Canyon abandoned because of human impact on the environment, or because of drought? The answer is: it was abandoned for both reasons. Over the course of six centuries the human population of Chaco Canyon grew, its demands on the environment grew, its environmental resources declined, and people came to be living increasingly close to the margin of what the environment could support. That was the *ultimate* cause of abandonment. The *proximate* cause, the proverbial last straw that broke the camel's back, was the drought that finally pushed Chacoans over the edge, a drought that a society living at a lower population density could have survived. When Chaco society did collapse, its inhabitants could no longer reconstruct their society in the way that the first farmers of the Chaco area had built up their society. The reason is that the initial conditions of abundant nearby trees, high groundwater levels, and a smooth floodplain without arroyos had disappeared.

That type of conclusion is likely to apply to many other collapses of past societies (including the Maya to be considered in the next chapter), and to our own destiny today. All of us moderns—house-owners, investors, politicians, university administrators, and others—can get away with a lot of waste when the economy is good. We forget that conditions fluctuate, and we may not be able to anticipate when conditions will change. By that time, we may already have become attached to an expensive lifestyle, leaving an enforced diminished lifestyle or bankruptcy as the sole outs.

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CHAPTER 5

The Maya Collapses

Mysteries of lost cities ▪ The Maya environment ▪ Maya agriculture ▪ Maya history ▪ Copán ▪ Complexities of collapses ▪ Wars and droughts ▪ Collapse in the southern lowlands ▪ The Maya message ▪

By now, millions of modern tourists have visited ruins of the ancient Maya civilization that collapsed over a thousand years ago in Mexico's Yucatán Peninsula and adjacent parts of Central America. All of us love a romantic mystery, and the Maya offer us one at our doorstep, almost as close for Americans as the Anasazi ruins. To visit a former Maya city, we need only board a direct flight from the U.S. to the modern Mexican state capital city of Mérida, jump into a rental car or minibus, and drive an hour on a paved highway (map, p. 161).

Today, many Maya ruins, with their great temples and monuments, still lie surrounded by jungle, far from current human settlement (Plate 12). Yet they were once the sites of the New World's most advanced Native American civilization before European arrival, and the only one with extensive deciphered written texts. How could ancient peoples have supported urban societies in areas where few farmers eke out a living today? The Maya cities impress us not only with that mystery and with their beauty, but also because they are "pure" archaeological sites. That is, their locations became depopulated, so they were not covered up by later buildings as were so many other ancient cities, like the Aztec capital of Tenochtitlán (now buried under modern Mexico City) and Rome.

Maya cities remained deserted, hidden by trees, and virtually unknown to the outside world until rediscovered in 1839 by a rich American lawyer named John Stephens, together with the English draftsman Frederick Catherwood. Having heard rumors of ruins in the jungle, Stephens got President Martin Van Buren to appoint him ambassador to the Confederation of Central American Republics, an amorphous political entity then extending from modern Guatemala to Nicaragua, as a front for his archaeological explorations. Stephens and Catherwood ended up exploring 44 sites and cities. From the extraordinary quality of the buildings and the art, they realized that these were not the work of savages (in their words) but of a vanished high civilization. They recognized that some of the carvings on the stone monuments constituted writing, and they correctly guessed that it related historical events and the names of people. On his return, Stephens wrote two travel books, illustrated by Catherwood and describing the ruins, that became best sellers.

A few quotes from Stephens's writings will give a sense of the romantic appeal of the Maya: "The city was desolate. No remnant of this race hangs round the ruins, with traditions handed down from father to son and from generation to generation. It lay before us like a shattered bark in the midst of the ocean, her mast gone, her name effaced, her crew perished, and none to tell whence she came, to whom she belonged, how long on her journey, or what caused her destruction. . . . Architecture, sculpture, and painting, all the arts which embellish life, had flourished in this overgrown forest; orators, warriors, and statesmen, beauty, ambition, and glory had lived and passed away, and none knew that such things had been, or could tell of their past existence. . . . Here were the remains of a cultivated, polished, and peculiar people, who had passed through all the stages incident to the rise and fall of nations; reached their golden age, and perished. . . . We went up to their desolate temples and fallen altars; and wherever we moved we saw the evidence of their taste, their skill in arts. . . . We called back into life the strange people who gazed in sadness from the wall; pictured them, in fanciful costumes and adorned with plumes of feather, ascending the terraces of the palace and the steps leading to the temples. . . . In the romance of the world's history nothing ever impressed me more forcibly than the spectacle of this once great and lovely city, overturned, desolate, and lost, . . . overgrown with trees for miles around, and without even a name to distinguish it." Those sensations are what tourists drawn to Maya ruins still feel today, and why we find the Maya collapse so fascinating.

The Maya story has several advantages for all of us interested in prehistoric collapses. First, the Maya written records that have survived, although frustratingly incomplete, are still useful for reconstructing Maya history in much greater detail than we can reconstruct Easter Island, or even Anasazi history with its tree rings and packrat middens. The great art and architecture of Maya cities have resulted in far more archaeologists studying the Maya than would have been the case if they had just been illiterate hunter-gatherers living in archaeologically invisible hovels. Climatologists and paleoecologists have recently been able to recognize several signals of ancient climate and environmental changes that contributed to the Maya collapse. Finally, today there are still Maya people living in their ancient homeland and speaking Maya languages. Because much ancient Maya culture survived the collapse, early European visitors to the homeland recorded information about contemporary Maya society that played a vital role in our understanding ancient Maya society. The first Maya contact with Europeans came already in 1502, just 10 years after Christopher Columbus's "discovery" of the New World, when Columbus on the last of his four voyages captured a trading canoe that may have been Maya. In 1527 the Spanish began in earnest to conquer the Maya, but it was not until 1697 that they subdued the last principality. Thus, the Spanish had opportunities to observe independent Maya societies for a period of nearly two centuries. Especially important, both for bad and for good, was the bishop Diego de Landa, who resided in the Yucatán Peninsula for most of the years from 1549 to 1578. On the one hand, in one of history's worst acts of cultural vandalism, he burned all Maya manuscripts that he could locate in his effort to eliminate "paganism," so that only four survive today. On the other hand, he wrote a detailed account of Maya society, and he obtained from an informant a garbled explanation of Maya writing that eventually, nearly four centuries later, turned out to offer clues to its decipherment.

A further reason for our devoting a chapter to the Maya is to provide an antidote to our other chapters on past societies, which consist disproportionately of small societies in somewhat fragile and geographically isolated environments, and behind the cutting edge of contemporary technology and culture. The Maya were none of those things. Instead, they were culturally the most advanced society (or among the most advanced ones) in the pre-Columbian New World, the only one with extensive preserved writing, and located within one of the two heartlands of New World civilization (Mesoamerica). While their environment did present some problems associated with its karst terrain and unpredictably fluctuating rainfall, it does not rank as notably fragile by world standards, and it was certainly less fragile than the environments of ancient Easter Island, the Anasazi area, Greenland, or modern Australia. Lest one be misled into thinking that crashes are a risk only for small peripheral societies in fragile areas, the Maya warn us that crashes can also befall the most advanced and creative societies.

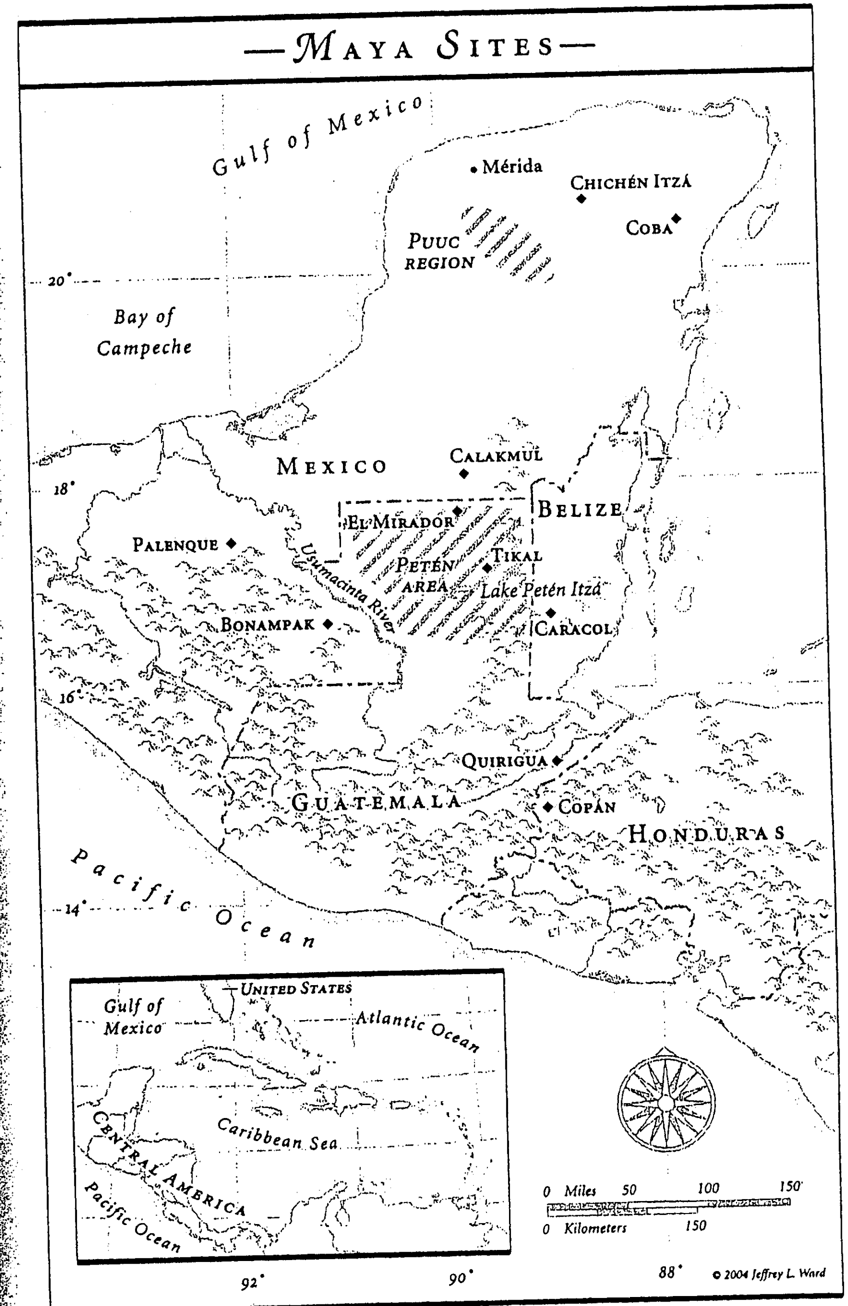
From the perspective of our five-point framework for understanding societal collapses, the Maya illustrate four of our points. They did damage their environment, especially by deforestation and erosion. Climate changes (droughts) did contribute to the Maya collapse, probably repeatedly. Hostilities among the Maya themselves did play a large role. Finally, political/

cultural factors, especially the competition among kings and nobles that led to a chronic emphasis on war and erecting monuments rather than on solving underlying problems, also contributed. The remaining item on our five-point list, trade or cessation of trade with external friendly societies, does not appear to have been essential in sustaining the Maya or in causing their downfall. While obsidian (their preferred raw material for making into stone tools), jade, gold, and shells were imported into the Maya area, the latter three items were non-essential luxuries. Obsidian tools remained widely distributed in the Maya area long after the political collapse, so obsidian was evidently never in short supply.

To understand the Maya, let's begin by considering their environment, which we think of as "jungle" or "tropical rainforest." That's not true, and the reason why not proves to be important. Properly speaking, tropical rainforests grow in high-rainfall equatorial areas that remain wet or humid all year round. But the Maya homeland lies more than a thousand miles from the equator, at latitudes 17° to 22°N, in a habitat termed a "seasonal tropical forest." That is, while there does tend to be a rainy season from May to October, there is also a dry season from January through April. If one focuses on the wet months, one calls the Maya homeland a "seasonal tropical forest"; if one focuses on the dry months, one could instead describe it as a "seasonal desert."

From north to south in the Yucatán Peninsula, rainfall increases from 18 to 100 inches per year, and the soils become thicker, so that the southern peninsula was agriculturally more productive and supported denser populations. But rainfall in the Maya homeland is unpredictably variable between years; some recent years have had three or four times more rain than other years. Also, the timing of rainfall within the year is somewhat unpredictable, so it can easily happen that farmers plant their crops in anticipation of rain and then the rains do not come when expected. As a result, modern farmers attempting to grow corn in the ancient Maya homelands have faced frequent crop failures, especially in the north. The ancient Maya were presumably more experienced and did better, but nevertheless they too must have faced risks of crop failures from droughts and hurricanes.

Although southern Maya areas received more rainfall than northern areas, problems of water were paradoxically more severe in the wet south. While that made things hard for ancient Maya living in the south, it has also made things hard for modern archaeologists who have difficulty under-



standing why ancient droughts would have caused bigger problems in the wet south than in the dry north. The likely explanation is that a lens of freshwater underlies the Yucatán Peninsula, but surface elevation increases from north to south, so that as one moves south the land surface lies increasingly higher above the water table. In the northern peninsula the elevation is sufficiently low that the ancient Maya were able to reach the water table at deep sinkholes called cenotes, or at deep caves; all tourists who have visited the Maya city of Chichén Itzá will remember the great cenotes there. In low-elevation north coastal areas without sinkholes, the Maya may have been able to get down to the water table by digging wells up to 75 feet deep. Water is readily available in many parts of Belize that have rivers, along the Usumacinta River in the west, and around a few lakes in the Petén area of the south. But much of the south lies too high above the water table for cenotes or wells to reach down to it. Making matters worse, most of the Yucatán Peninsula consists of karst, a porous sponge-like limestone terrain where rain runs straight into the ground and where little or no surface water remains available.

How did those dense southern Maya populations deal with their resulting water problem? It initially surprises us that many of their cities were not built next to the few rivers but instead on promontories in rolling uplands. The explanation is that the Maya excavated depressions, modified natural depressions, and then plugged up leaks in the karst by plastering the bottoms of the depressions in order to create cisterns and reservoirs, which collected rain from large plastered catchment basins and stored it for use in the dry season. For example, reservoirs at the Maya city of Tikal held enough water to meet the drinking water needs of about 10,000 people for a period of 18 months. At the city of Coba the Maya built dikes around a lake in order to raise its level and make their water supply more reliable. But the inhabitants of Tikal and other cities dependent on reservoirs for drinking water would still have been in deep trouble if 18 months passed without rain in a prolonged drought. A shorter drought in which they exhausted their stored food supplies might already have gotten them in deep trouble through starvation, because growing crops required rain rather than reservoirs.

Of particular importance for our purposes are the details of Maya agriculture, which was based on crops domesticated in Mexico—especially corn, with beans being second in importance. For the elite as well as commoners, corn constituted at least 70% of the Maya diet, as deduced from isotope analyses of ancient Maya skeletons. Their sole domestic animals were the dog, turkey, Muscovy duck, and a stingless bee yielding honey, while their most important wild meat source was deer that they hunted, plus fish at some sites. However, the few animal bones at Maya archaeological sites suggest that the quantity of meat available to the Maya was low. Venison was mainly a luxury food for the elite.

It was formerly believed that Maya farming was based on slash-and-burn agriculture (so-called swidden agriculture) in which forest is cleared and burned, crops are grown in the resulting field for a year or a few years until the soil is exhausted, and then the field is abandoned for a long fallow period of 15 or 20 years until regrowth of wild vegetation restores fertility to the soil. Because most of the landscape under a swidden agricultural system is fallow at any given time, it can support only modest population densities. Thus, it was a surprise for archaeologists to discover that ancient Maya population densities, estimated from numbers of stone foundations of farmhouses, were often far higher than what swidden agriculture could support. The actual values are the subject of much dispute and evidently varied among areas, but frequently cited estimates reach 250 to 750, possibly even 1,500, people per square mile. (For comparison, even today the two most densely populated countries in Africa, Rwanda and Burundi, have population densities of only about 750 and 540 people per square mile, respectively.) Hence the ancient Maya must have had some means of increasing agricultural production beyond what was possible through swidden alone.

Many Maya areas do show remains of agricultural structures designed to increase production, such as terracing of hill slopes to retain soil and moisture, irrigation systems, and arrays of canals and drained or raised fields. The latter systems, which are well attested elsewhere in the world and which require a lot of labor to construct, but which reward the labor with increased food production, involve digging canals to drain a waterlogged area, fertilizing and raising the level of the fields between the canals by dumping muck and water hyacinths dredged out of canals onto the fields, and thereby keeping the fields themselves from being inundated. Besides harvesting crops grown over the fields, farmers with raised fields also "grow" wild fish and turtles in the canals (actually, let them grow themselves) as an additional food source. However, other Maya areas, such as the well-studied cities of Copán and Tikal, show little archaeological evidence of terracing, irrigation, or raised- or drained-field systems. Instead, their inhabitants must have used archaeologically invisible means to increase food production, by mulching, floodwater farming, shortening the time that a field is left fallow, and tilling the soil to restore soil fertility, or in the extreme omitting the fallow period entirely and growing crops every year, or in especially moist areas growing two crops per year.

Socially stratified societies, including modern American and European society, consist of farmers who produce food, plus non-farmers such as bureaucrats and soldiers who do not produce food but merely consume the food grown by the farmers and are in effect parasites on farmers. Hence in any stratified society the farmers must grow enough surplus food to meet not only their own needs but also those of the other consumers. The number of non-producing consumers that can be supported depends on the society's agricultural productivity. In the United States today, with its highly efficient agriculture, farmers make up only 2% of our population, and each farmer can feed on the average 125 other people (American non-farmers plus people in export markets overseas). Ancient Egyptian agriculture, although much less efficient than modern mechanized agriculture, was still efficient enough for an Egyptian peasant to produce five times the food required for himself and his family. But a Maya peasant could produce only twice the needs of himself and his family. At least 70% of Maya society consisted of peasants. That's because Maya agriculture suffered from several limitations.

First, it yielded little protein. Corn, by far the dominant crop, has a lower protein content than the Old World staples of wheat and barley. The few edible domestic animals already mentioned included no large ones and yielded much less meat than did Old World cows, sheep, pigs, and goats. The Maya depended on a narrower range of crops than did Andean farmers (who in addition to corn also had potatoes, high-protein quinoa, and many other plants, plus llamas for meat), and much narrower again than the variety of crops in China and in western Eurasia.

Another limitation was that Maya corn agriculture was less intensive and productive than the Aztecs' *chinampas* (a very productive type of raised-field agriculture), the raised fields of the Tiwanaku civilization of the Andes, Moche irrigation on the coast of Peru, or fields tilled by animal-drawn plows over much of Eurasia.

Still a further limitation arose from the humid climate of the Maya area, which made it difficult to store corn beyond a year, whereas the Anasazi living in the dry climate of the U.S. Southwest could store it for three years.

Finally, unlike Andean Indians with their llamas, and unlike Old World peoples with their horses, oxen, donkeys, and camels, the Maya had no animal-powered transport or plows. All overland transport for the Maya went on the backs of human porters. But if you send out a porter carrying a load of corn to accompany an army into the field, some of that load of corn is required to feed the porter himself on the trip out, and some more to feed him on the trip back, leaving only a fraction of the load available to feed the army. The longer the trip, the less of the load is left over from the porter's own requirements. Beyond a march of a few days to a week, it becomes uneconomical to send porters carrying corn to provision armies or markets. Thus, the modest productivity of Maya agriculture, and their lack of draft animals, severely limited the duration and distance possible for their military campaigns.

We are accustomed to thinking of military success as determined by quality of weaponry, rather than by food supply. But a clear example of how improvements in food supply may decisively increase military success comes from the history of Maori New Zealand. The Maori are the Polynesian people who were the first to settle New Zealand. Traditionally, they fought frequent fierce wars against each other, but only against closely neighboring tribes. Those wars were limited by the modest productivity of their agriculture, whose staple crop was sweet potatoes. It was not possible to grow enough sweet potatoes to feed an army in the field for a long time or on distant marches. When Europeans arrived in New Zealand, they brought potatoes, which beginning around 1815 considerably increased Maori crop yields. Maori could now grow enough food to supply armies in the field for many weeks. The result was a 15-year period in Maori history, from 1818 until 1833, when Maori tribes that had acquired potatoes and guns from the English sent armies out on raids to attack tribes hundreds of miles away that had not yet acquired potatoes and guns. Thus, the potato's productivity relieved previous limitations on Maori warfare, similar to the limitations that low-productivity corn agriculture imposed on Maya warfare.

Those food supply considerations may contribute to explaining why Maya society remained politically divided among small kingdoms that were perpetually at war with each other, and that never became unified into large empires like the Aztec Empire of the Valley of Mexico (fed with the help of their *chinampa* agriculture and other forms of intensification) or the Inca Empire of the Andes (fed by more diverse crops carried by llamas over well-built roads). Maya armies and bureaucracies remained small and unable to mount lengthy campaigns over long distances. (Even much later, in 1848, when the Maya revolted against their Mexican overlords and a Maya army seemed to be on the verge of victory, the army had to break off fighting and go home to harvest another crop of corn.) Many Maya kingdoms held populations of only up to 25,000 to 50,000 people, none over half a million, within a radius of two or three days' walk from the king's palace. (The actual numbers are again highly controversial among archaeologists.) From the tops of the temples of some Maya kingdoms, it was possible to see the temples of the nearest kingdom. Maya cities remained small (mostly less than one square mile in area), without the large populations and big markets of Teotihuacán and Tenochtitlán in the Valley of Mexico, or of Chan-Chan and Cuzco in Peru, and without archaeological evidence of the royally managed food storage and trade that characterized ancient Greece and Mesopotamia.

Now for a quick crash-course in Maya history. The Maya area is part of the larger ancient Native American cultural region known as Mesoamerica, which extended approximately from Central Mexico to Honduras and constituted (along with the Andes of South America) one of the two New World centers of innovation before European arrival. The Maya shared much in common with other Mesoamerican societies not only in what they possessed, but also in what they lacked. For example, surprisingly to modern Westerners with expectations based on Old World civilizations, Mesoamerican societies lacked metal tools, pulleys and other machines, wheels (except locally as toys), boats with sails, and domestic animals large enough to carry loads or pull a plow. All of those great Maya temples were constructed by stone and wooden tools and by human muscle power alone.

Of the ingredients of Maya civilization, many were acquired by the Maya from elsewhere in Mesoamerica. For instance, Mesoamerican agriculture, cities, and writing first arose outside the Maya area itself, in valleys and coastal lowlands to the west and southwest, where corn and beans and squash were domesticated and became important dietary components by 3000 B.C., pottery arose around 2500 B.C., villages by 1500 B.C., cities among the Olmecs by 1200 B.C., writing appeared among the Zapotecs in Oaxaca around or after 600 B.C., and the first states arose around 300 B.C. Two complementary calendars, a solar calendar of 365 days and a ritual calendar of 260 days, also arose outside the Maya area. Other elements of Maya civilization were either invented, perfected, or modified by the Maya themselves.

Within the Maya area, villages and pottery appeared around or after 1000 B.C., substantial buildings around 500 B.C., and writing around 400 B.C. All preserved ancient Maya writing, constituting a total of about 15,000 inscriptions, is on stone and pottery and deals only with kings, nobles, and their conquests (Plate 13). There is not a single mention of commoners. When Spaniards arrived, the Maya were still using bark paper coated with plaster to write books, of which the sole four that escaped Bishop Landa's fires turned out to be treatises on astronomy and the calendar. The ancient Maya also had had such bark-paper books, often depicted on their pottery, but only decayed remains of them have survived in tombs.

The famous Maya Long Count calendar begins on August 11, 3114 B.C.—just as our own calendar begins on January 1 of the first year of the Christian era. We know the significance to us of that day-zero of our calendar: it's the supposed beginning of the year in which Christ was born. Presumably the Maya also attached some significance to their own day zero, but we don't know what it was. The first preserved Long Count date is only A.D. 197 for a monument in the Maya area and 36 B.C. outside the Maya area, indicating that the Long Count calendar's day-zero was backdated to August 11, 3114 B.C. long after the facts; there was no writing anywhere in the New World then, nor would there be for 2,500 years after that date.

Our calendar is divided into units of days, weeks, months, years, decades, centuries, and millennia: for example, the date of February 19, 2003, on which I wrote the first draft of this paragraph, means the 19th day of the second month in the third year of the first decade of the first century of the third millennium beginning with the birth of Christ. Similarly, the Maya Long Count calendar named dates in units of days *(kin)*, 20 days *(uinal)*, 360 days *(tun)*, 7,200 days or approximately 20 years *(katunn)*, and 144,000 days or approximately 400 years *(baktun)*. All of Maya history falls into baktuns 8, 9, and 10.

The so-called Classic period of Maya civilization begins in baktun 8, around A.D. 250, when evidence for the first kings and dynasties appears. Among the glyphs (written signs) on Maya monuments, students of Maya writing recognized a few dozen, each of which was concentrated in its own geographic area, and which are now considered to have had the approximate meaning of dynasties or kingdoms. In addition to Maya kings having their own name glyphs and palaces, many nobles also had their own inscriptions and palaces. In Maya society the king also functioned as high priest carrying the responsibility to attend to astronomical and calendrical rituals, and thereby to bring rain and prosperity, which the king claimed to have the supernatural power to deliver because of his asserted family relationship to the gods. That is, there was a tacitly understood quid pro quo:

the reason why the peasants supported the luxurious lifestyle of the king and his court, fed him corn and venison, and built his palaces was because he had made implicit big promises to the peasants. As we shall see, kings got into trouble with their peasants if a drought came, because that was tantamount to the breaking of a royal promise.

From A.D. 250 onwards, the Maya population (as judged from the number of archaeologically attested house sites), the number of monuments and buildings, and the number of Long Count dates on monuments and pottery increased almost exponentially, to reach peak numbers in the 8th century A.D. The largest monuments were erected towards the end of that Classic period. Numbers of all three of those indicators of a complex society declined throughout the 9th century, until the last known Long Count date on any monument fell in baktun 10, in the year A.D. 909. That decline of Maya population, architecture, and the Long Count calendar constitutes what is known as the Classic Maya collapse.

As an example of the collapse, let's consider in more detail a small but densely built city whose ruins now lie in western Honduras at a site known as Copán, and described in two recent books by archaeologist David Webster. For agricultural purposes the best land in the Copán area consists of five pockets of flat land with fertile alluvial soil along a river valley, with a tiny total area of only 10 square miles; the largest of those five pockets, known as the Copán pocket, has an area of only 5 square miles. Much of the land around Copán consists of steep hills, and nearly half of the hill area has a slope above 16% (approximately double the slope of the steepest grade that you are likely to encounter on an American highway). Soil in the hills is less fertile, more acidic, and poorer in phosphate than valley soil. Today, corn yields from valley-bottom fields are two or three times those of fields on hill slopes, which suffer rapid erosion and lose three-quarters of their productivity within a decade of farming.

As judged by numbers of house sites, population growth in the Copán Valley rose steeply from the 5th century up to a peak estimated at around 27,000 people at A.D. 750–900. Maya written history at Copán begins in the year with a Long Count date corresponding to A.D. 426, when later monuments record retrospectively that some person related to nobles at Tikal and Teotihuacán arrived. Construction of royal monuments glorifying kings was especially massive between A.D. 650 and 750. After A.D. 700, nobles other than kings also got into the act and began erecting their own palaces,

of which there were about twenty by the year A.D. 800, when one of those palaces is known to have consisted of 50 buildings with room for about 250 people. All of those nobles and their courts would have increased the burden that the king and his own court imposed on the peasants. The last big buildings at Copán were put up around A.D. 800, and the last Long Count date on an incomplete altar possibly bearing a king's name has the date of A.D. 822.

Archaeological surveys of different types of habitats in the Copán Valley show that they were occupied in a regular sequence. The first area farmed was the large Copán pocket of valley bottomland, followed by occupation of the other four bottomland pockets. During that time the human population was growing, but there was not yet occupation of the hills. Hence that increased population must have been accommodated by intensifying production in the bottomland pockets by some combination of shorter fallow periods, double-cropping, and possibly some irrigation.

By the year A.D. 650, people started to occupy the hill slopes, but those hill sites were cultivated only for about a century. The percentage of Copán's total population that was in the hills, rather than in the valleys, reached a maximum of 41%, then declined until the population again became concentrated in the valley pockets. What caused that pullback of population from the hills? Excavation of the foundations of buildings in the valley floor showed that they became covered with sediment during the 8th century, meaning that the hill slopes were getting eroded and probably also leached of nutrients. Those acidic infertile hill soils were being carried down into the valley and blanketing the more fertile valley soils, where they would have reduced agricultural yields. This ancient quick abandonment of hillsides coincides with modern Maya experience that fields in the hills have low fertility and that their soils become rapidly exhausted.

The reason for that erosion of the hillsides is clear: the forests that formerly covered them and protected their soils were being cut down. Dated pollen samples show that the pine forests originally covering the upper elevations of the hill slopes were eventually all cleared. Calculation suggests that most of those felled pine trees were being burned for fuel, while the rest were used for construction or for making plaster. At other Maya sites from the pre-Classic era, where the Maya went overboard in lavish use of thick plaster on buildings, plaster production may have been a major cause of deforestation. Besides causing sediment accumulation in the valleys and depriving valley inhabitants of wood supplies, that deforestation may have begun to cause a "man-made drought" in the valley bottom, because forests play a major role in water cycling, such that massive deforestation tends to result in lowered rainfall.

Hundreds of skeletons recovered from Copán archaeological sites have been studied for signs of disease and malnutrition, such as porous bones and stress lines in the teeth. These skeletal signs show that the health of Copán's inhabitants deteriorated from A.D. 650 to 850, both among the elite and among the commoners, although the health of commoners was worse.

Recall that Copán's population was increasing steeply while the hills were being occupied. The subsequent abandonment of all of those fields in the hills meant that the burden of feeding the extra population formerly dependent on the hills now fell increasingly on the valley floor, and that more and more people were competing for the food grown on those 10 square miles of valley bottomland. That would have led to fighting among the farmers themselves for the best land, or for any land, just as in modern Rwanda (Chapter 10). Because Copán's king was failing to deliver on his promises of rain and prosperity in return for the power and luxuries that he claimed, he would have been the scapegoat for this agricultural failure. That may explain why the last that we hear from any Copán king is A.D. 822 (that last Long Count date at Copán), and why the royal palace was burned around A.D. 850. However, the continued production of some luxury goods suggest that some nobles managed to carry on with their lifestyle after the king's downfall, until around A.D. 975.

To judge from datable pieces of obsidian, Copán's total population decreased more gradually than did its signs of kings and nobles. The estimated population in the year A.D. 950 was still around 15,000, or 54% of the peak population of 27,000. That population continued to dwindle, until there are no more signs of anyone in the Copán Valley by around A.D. 1250. The reappearance of pollen from forest trees thereafter provides independent evidence that the valley became virtually empty of people, and that the forests could at last begin to recover.

The general outline of Maya history that I have just related, and the example of Copán's history in particular, illustrates why we talk about "the Maya collapse." But the story grows more complicated, for at least five reasons.

First, there was not only that enormous Classic collapse, but at least two previous smaller collapses at some sites, one around the year A.D. 150 when El Mirador and some other Maya cities collapsed (the so-called pre-Classic collapse), the other (the so-called Maya hiatus) in the late 6th century and early 7th century, a period when no monuments were erected at the well-studied site of Tikal. There were also some post-Classic collapses in areas whose populations survived the Classic collapse or increased after it—such as the fall of Chichén Itzá around 1250 and of Mayapán around 1450.

Second, the Classic collapse was obviously not complete, because there were hundreds of thousands of Maya who met and fought the Spaniards—far fewer Maya than during the Classic peak, but still far more people than in the other ancient societies discussed in detail in this book. Those survivors were concentrated in areas with stable water supplies, especially in the north with its cenotes, the coastal lowlands with their wells, near a southern lake, and along rivers and lagoons at lower elevations. However, population otherwise disappeared almost completely in what previously had been the Maya heartland in the south.

Third, the collapse of population (as gauged by numbers of house sites and of obsidian tools) was in some cases much slower than the decline in numbers of Long Count dates, as I already mentioned for Copán. What collapsed quickly during the Classic collapse was the institution of kingship and the Long Count calendar.

Fourth, many apparent collapses of cities were really nothing more than "power cycling": i.e., particular cities becoming more powerful, then declining or getting conquered, and then rising again and conquering their neighbors, without changes in the whole population. For example, in the year 562 Tikal was defeated by its rivals Caracol and Calakmul, and its king was captured and killed. However, Tikal then gradually gained strength again and finally conquered its rivals in 695, long before Tikal joined many other Maya cities in the Classic collapse (last dated Tikal monuments A.D. 869). Similarly, Copán grew in power until the year 738, when its king Waxaklahuun Ub'aah K'awil (a name better known to Maya enthusiasts today by its unforgettable translation of "18 Rabbit") was captured and put to death by the rival city of Quirigua, but then Copán thrived during the following half-century under more fortunate kings.

Finally, cities in different parts of the Maya area rose and fell on different trajectories. For example, the Puuc region in the northwest Yucatán Peninsula, after being almost empty of people in the year 700, exploded in population after 750 while the southern cities were collapsing, peaked in population between 900 and 925, and then collapsed in turn between 950 and 1000. El Mirador, a huge site in the center of the Maya area with one of the world's largest pyramids, was settled in 200 B.C. and abandoned around A.D. 150, long before the rise of Copán. Chichén Itzá in the northern peninsula grew after A.D. 850 and was the main northern center around 1000, only to be destroyed in a civil war around 1250.

Some archaeologists focus on these five types of complications and don't want to recognize a Classic Maya collapse at all. But this overlooks the obvious facts that cry out for explanation: the disappearance of between 90 and 99% of the Maya population after A.D. 800, especially in the formerly most densely populated area of the southern lowlands, and the disappearance of kings, Long Count calendars, and other complex political and cultural institutions. That's why we talk about a Classic Maya collapse, a collapse both of population and of culture that needs explaining.

Two other phenomena that I have mentioned briefly as contributing to Maya collapses require more discussion: the roles of warfare and of drought.

Archaeologists for a long time believed the ancient Maya to be gentle and peaceful people. We now know that Maya warfare was intense, chronic, and unresolvable, because limitations of food supply and transportation made it impossible for any Maya principality to unite the whole region in an empire, in the way that the Aztecs and Incas united Central Mexico and the Andes, respectively. The archaeological record shows that wars became more intense and frequent towards the time of the Classic collapse. That evidence comes from discoveries of several types over the last 55 years: archaeological excavations of massive fortifications surrounding many Maya sites; vivid depictions of warfare and captives on stone monuments, vases (Plate 14), and on the famous painted murals discovered in 1946 at Bonampak; and the decipherment of Maya writing, much of which proved to consist of royal inscriptions boasting of conquests. Maya kings fought to take one another captive, one of the unfortunate losers being Copán's King 18 Rabbit. Captives were tortured in unpleasant ways depicted clearly on the monuments and murals (such as yanking fingers out of sockets, pulling out teeth, cutting off the lower jaw, trimming off the lips and fingertips, pulling out the fingernails, and driving a pin through the lips), culminating (sometimes several years later) in the sacrifice of the captive in other equally unpleasant ways (such as tying the captive up into a ball by binding the arms and legs together, then rolling the balled-up captive down the steep stone staircase of a temple).

Maya warfare involved several well-documented types of violence: wars

between separate kingdoms; attempts of cities within a kingdom to secede by revolting against the capital; and civil wars resulting from frequent violent attempts by would-be kings to usurp the throne. All of these types were described or depicted on monuments, because they involved kings and nobles. Not considered worthy of description, but probably even more frequent, were fights between commoners over land, as overpopulation became excessive and as land became scarce.

The other phenomenon important to understanding Maya collapses is the repeated occurrence of droughts, studied especially by Mark Brenner, David Hodell, the late Edward Deevey, and their colleagues at the University of Florida, and discussed in a recent book by Richardson Gill. Cores bored into layers of sediments at the bottoms of Maya lakes yield many measurements that let us infer droughts and environmental changes. For example, gypsum (a.k.a. calcium sulfate) precipitates out of solution in a lake into sediments when lake water becomes concentrated by evaporation during a drought. Water containing the heavy form of oxygen known as the isotope oxygen-18 also becomes concentrated during droughts, while water containing the lighter isotope oxygen-16 evaporates away. Molluscs and crustacea living in the lake take up oxygen to lay down in their shells, which remain preserved in the lake sediments, waiting for climatologists to analyze for those oxygen isotopes long after the little animals have died. Radiocarbon dating of a sediment layer identifies the approximate year when the drought or rainfall conditions inferred from those gypsum and oxygen isotope measurements were prevailing. The same lake sediment cores provide palynologists with information about deforestation (which shows up as a decrease in pollen from forest trees at the expense of an increase in grass pollen), and also soil erosion (which shows up as a thick clay deposit and minerals from the washed-down soil).

Based on these studies of radiocarbon-dated layers from lake sediment cores, climatologists and paleoecologists conclude that the Maya area was relatively wet from about 5500 B.C. until 500 B.C. The following period from 475 to 250 B.C., just before the rise of pre–Classic Maya civilization, was dry. The pre-Classic rise may have been facilitated by the return of wetter conditions after 250 B.C., but then a drought from A.D. 125 until A.D. 250 was associated with the pre-Classic collapse at El Mirador and other sites. That collapse was followed by the resumption of wetter conditions and of the buildup of Classic Maya cities, temporarily interrupted by a drought around A.D. 600 corresponding to a decline at Tikal and some other sites. Finally, around A.D. 760 there began the worst drought in the last 7,000 years, peaking around the year A.D. 800, and suspiciously associated with the Classic collapse.

Careful analysis of the frequency of droughts in the Maya area shows a tendency for them to recur at intervals of about 208 years. Those drought cycles may result from small variations in the sun's radiation, possibly made more severe in the Maya area as a result of the rainfall gradient in the Yucatán (drier in the north, wetter in the south) shifting southwards. One might expect those changes in the sun's radiation to affect not just the Maya region but, to varying degrees, the whole world. In fact, climatologists have noted that some other famous collapses of prehistoric civilizations far from the Maya realm appear to coincide with the peaks of those drought cycles, such as the collapse of the world's first empire (the Akkadian Empire of Mesopotamia) around 2170 B.C., the collapse of Moche IV civilization on the Peruvian coast around A.D. 600, and the collapse of Tiwanaku civilization in the Andes around A.D. 1100.

In the most naïve form of the hypothesis that drought contributed to causing the Classic collapse, one could imagine a single drought around A.D. 800 uniformly affecting the whole realm and triggering the fall of all Maya centers simultaneously. Actually, as we have seen, the Classic collapse hit different centers at slightly different times in the period A.D. 760–910, while sparing other centers. That fact makes many Maya specialists skeptical of a role of drought.

But a properly cautious climatologist would not state the drought hypothesis in that implausibly oversimplied form. Finer-resolution variation in rainfall from one year to the next can be calculated from annually banded sediments that rivers wash into ocean basins near the coast. These yield the conclusion that "The Drought" around A.D. 800 actually had four peaks, the first of them less severe: two dry years around A.D. 760, then an even drier decade around A.D. 810–820, three drier years around A.D. 860, and six drier years around A.D. 910. Interestingly, Richardson Gill concluded, from the latest dates on stone monuments at various large Maya centers, that collapse dates vary among sites and fall into three clusters: around A.D. 810, 860, and 910, in agreement with the dates for the three most severe droughts. It would not be at all surprising if a drought in any given year varied locally in its severity, hence if a series of droughts caused different Maya centers to collapse in different years, while sparing centers with reliable water supplies such as cenotes, wells, and lakes.

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The area most affected by the Classic collapse was the southern lowlands, probably for the two reasons already mentioned: it was the area with the densest population, and it may also have had the most severe water problems because it lay too high above the water table for water to be obtained from cenotes or wells when the rains failed. The southern lowlands lost more than 99% of their population in the course of the Classic collapse. For example, the population of the Central Petén at the peak of the Classic Maya period is variously estimated at between 3,000,000 and 14,000,000 people, but there were only about 30,000 people there at the time that the Spanish arrived. When Cortés and his Spanish army passed through the Central Petén in 1524 and 1525, they nearly starved because they encountered so few villages from which to acquire corn. Cortés passed within a few miles of the ruins of the great Classic cities of Tikal and Palenque, but he heard or saw nothing of them because they were covered by jungle and almost nobody was living in the vicinity.

How did such a huge population of millions of people disappear? We asked ourselves that same question about the disappearance of Chaco Canyon's (admittedly smaller) Anasazi population in Chapter 4. By analogy with the cases of the Anasazi and of subsequent Pueblo Indian societies during droughts in the U.S. Southwest, we infer that some people from the southern Maya lowlands survived by fleeing to areas of the northern Yucatán endowed with cenotes or wells, where a rapid population increase took place around the time of the Maya collapse. But there is no sign of all those millions of southern lowland inhabitants surviving to be accommodated as immigrants in the north, just as there is no sign of thousands of Anasazi refugees being received as immigrants into surviving pueblos. As in the U.S. Southwest during droughts, some of that Maya population decrease surely involved people dying of starvation or thirst, or killing each other in struggles over increasingly scarce resources. The other part of the decrease may reflect a slower decrease in the birthrate or child survival rate over the course of many decades. That is, depopulation probably involved both a higher death rate and a lower birth rate.

In the Maya area as elsewhere, the past is a lesson for the present. From the time of Spanish arrival, the Central Petén's population declined further to about 3,000 in A.D. 1714, as a result of deaths from diseases and other causes associated with Spanish occupation. By the 1960s, the Central Petén's population had risen back only to 25,000, still less than 1% of what it had been at the Classic Maya peak. Thereafter, however, immigrants flooded into the Central Petén, building up its population to about 300,000 in the 1980s, and ushering in a new era of deforestation and erosion. Today, half of the Petén is once again deforested and ecologically degraded. One-quarter of all the forests of Honduras were destroyed between 1964 and 1989.

To summarize the Classic Maya collapse, we can tentatively identify five strands. I acknowledge, however, that Maya archaeologists still disagree vigorously among themselves—in part, because the different strands evidently varied in importance among different parts of the Maya realm; because detailed archaeological studies are available for only some Maya sites; and because it remains puzzling why most of the Maya heartland remained nearly empty of population and failed to recover after the collapse and after regrowth of forests.

With those caveats, it appears to me that one strand consisted of population growth outstripping available resources: a dilemma similar to the one foreseen by Thomas Malthus in 1798 and being played out today in Rwanda (Chapter 10), Haiti (Chapter 11), and elsewhere. As the archaeologist David Webster succinctly puts it, "Too many farmers grew too many crops on too much of the landscape." Compounding that mismatch between population and resources was the second strand: the effects of deforestation and hillside erosion, which caused a decrease in the amount of useable farmland at a time when more rather than less farmland was needed, and possibly exacerbated by an anthropogenic drought resulting from deforestation, by soil nutrient depletion and other soil problems, and by the struggle to prevent bracken ferns from overrunning the fields.

The third strand consisted of increased fighting, as more and more people fought over fewer resources. Maya warfare, already endemic, peaked just before the collapse. That is not surprising when one reflects that at least 5,000,000 people, perhaps many more, were crammed into an area smaller than the state of Colorado (104,000 square miles). That warfare would have decreased further the amount of land available for agriculture, by creating no-man's lands between principalities where it was now unsafe to farm. Bringing matters to a head was the strand of climate change. The drought at the time of the Classic collapse was not the first drought that the Maya had lived through, but it was the most severe. At the time of previous droughts, there were still uninhabited parts of the Maya landscape, and people at a site affected by drought could save themselves by moving to another site. However, by the time of the Classic collapse the landscape was now full, there

was no useful unoccupied land in the vicinity on which to begin anew, and the whole population could not be accommodated in the few areas that continued to have reliable water supplies.

As our fifth strand, we have to wonder why the kings and nobles failed to recognize and solve these seemingly obvious problems undermining their society. Their attention was evidently focused on their short-term concerns of enriching themselves, waging wars, erecting monuments, competing with each other, and extracting enough food from the peasants to support all those activities. Like most leaders throughout human history, the Maya kings and nobles did not heed long-term problems, insofar as they perceived them. We shall return to this theme in Chapter 14.

Finally, while we still have some other past societies to consider in this book before we switch our attention to the modern world, we must already be struck by some parallels between the Maya and the past societies discussed in Chapters 2–4. As on Easter Island, Mangareva, and among the Anasazi, Maya environmental and population problems led to increasing warfare and civil strife. As on Easter Island and at Chaco Canyon, Maya peak population numbers were followed swiftly by political and social collapse. Paralleling the eventual extension of agriculture from Easter Island's coastal lowlands to its uplands, and from the Mimbres floodplain to the hills, Copán's inhabitants also expanded from the floodplain to the more fragile hill slopes, leaving them with a larger population to feed when the agricultural boom in the hills went bust. Like Easter Island chiefs erecting ever larger statues, eventually crowned by pukao, and like Anasazi elite treating themselves to necklaces of 2,000 turquoise beads, Maya kings sought to outdo each other with more and more impressive temples, covered with thicker and thicker plaster—reminiscent in turn of the extravagant conspicuous consumption by modern American CEOs. The passivity of Easter chiefs and Maya kings in the face of the real big threats to their societies completes our list of disquieting parallels.

CHAPTER 16

The World as a Polder: What Does It All Mean to Us Today?

Introduction ■ The most serious problems ■ If we don't solve them . . . ■ Life in Los Angeles ■ One-liner objections ■ The past and the present ■ Reasons for hope ■

The chapters of this book have discussed why past or present societies succeed or fail at solving their environmental problems. Now, this final chapter considers the book's practical relevance: what does it all mean to us today?

I shall begin by explaining the major sets of environmental problems facing modern societies, and the time scale on which they pose threats. As a specific example of how these problems play out, I examine the area where I have spent most of the last 39 years of my life, Southern California. I then consider the objections most often raised to dismiss the significance of environmental problems today. Since half of this book was devoted to ancient societies because of the lessons that they might hold for modern societies, I look at differences between the ancient and the modern worlds that affect what lessons we can draw from the past. Finally, for anyone who asks, "What can I do as an individual?" I offer suggestions in the Further Readings section.

It seems to me that the most serious environmental problems facing past and present societies fall into a dozen groups. Eight of the 12 were significant already in the past, while four (numbers 5, 7, 8, and 10: energy, the photosynthetic ceiling, toxic chemicals, and atmospheric changes) became serious only recently. The first four of the 12 consist of destruction or losses of natural resources; the next three involve ceilings on natural resources; the three after that consist of harmful things that we produce or move around; and the last two are population issues. Let's begin with the natural resources

that we are destroying or losing: natural habitats, wild food sources, biological diversity, and soil.

1. At an accelerating rate, we are destroying natural habitats or else converting them to human-made habitats, such as cities and villages, farmlands and pastures, roads, and golf courses. The natural habitats whose losses have provoked the most discussion are forests, wetlands, coral reefs, and the ocean bottom. As I mentioned in the preceding chapter, more than half of the world's original area of forest has already been converted to other uses, and at present conversion rates one-quarter of the forests that remain will become converted within the next half-century. Those losses of forests represent losses for us humans, especially because forests provide us with timber and other raw materials, and because they provide us with so-called ecosystem services such as protecting our watersheds, protecting soil against erosion, constituting essential steps in the water cycle that generates much of our rainfall, and providing habitat for most terrestrial plant and animal species. Deforestation was a or *the* major factor in all the collapses of past societies described in this book. In addition, as discussed in Chapter 1 in connection with Montana, issues of concern to us are not only forest destruction and conversion, but also changes in the structure of wooded habitats that do remain. Among other things, that changed structure results in changed fire regimes that put forests, chaparral woodlands, and savannahs at greater risk of infrequent but catastrophic fires.

Other valuable natural habitats besides forests are also being destroyed. An even larger fraction of the world's original wetlands than of its forests has already been destroyed, damaged, or converted. Consequences for us arise from wetlands' importance in maintaining the quality of our water supplies and the existence of commercially important freshwater fisheries, while even ocean fisheries depend on mangrove wetlands to provide habitat for the juvenile phase of many fish species. About one-third of the world's coral reefs—the oceanic equivalent of tropical rainforests, because they are home to a disproportionate fraction of the ocean's species—have already been severely damaged. If current trends continue, about half of the remaining reefs would be lost by the year 2030. That damage and destruction result from the growing use of dynamite as a fishing method, reef overgrowth by algae ("seaweeds") when the large herbivorous fish that normally graze on the algae become fished out, effects of sediment runoff and pollutants from adjacent lands cleared or converted to agriculture, and coral bleaching due to rising ocean water temperatures. It has recently become appreciated that fishing by trawling is destroying much or most of the shallow ocean bottom and the species dependent on it.

2. Wild foods, especially fish and to a lesser extent shellfish, contribute a large fraction of the protein consumed by humans. In effect, this is protein that we obtain for free (other than the cost of catching and transporting the fish), and that reduces our needs for animal protein that we have to grow ourselves in the form of domestic livestock. About two billion people, most of them poor, depend on the oceans for protein. If wild fish stocks were managed appropriately, the stock levels could be maintained, and they could be harvested perpetually. Unfortunately, the problem known as the tragedy of the commons (Chapter 14) has regularly undone efforts to manage fisheries sustainably, and the great majority of valuable fisheries already either have collapsed or are in steep decline (Chapter 15). Past societies that overfished included Easter Island, Mangareva, and Henderson.

Increasingly, fish and shrimp are being grown by aquaculture, which in principle has a promising future as the cheapest way to produce animal protein. In several respects, though, aquaculture as commonly practiced today is making the problem of declining wild fisheries worse rather than better. Fish grown by aquaculture are mostly fed wild-caught fish and thereby usually consume more wild fish meat (up to 20 times more) than they yield in meat of their own They contain higher toxin levels than do wild-caught fish. Cultured fish regularly escape, interbreed with wild fish, and thereby harm wild fish stocks genetically, because cultured fish strains have been selected for rapid growth at the expense of poor survival in the wild (50 times worse survival for cultured salmon than for wild salmon). Aquaculture runoff causes pollution and eutrophication. The lower costs of aquaculture than of fishing, by driving down fish prices, initially drive fishermen to exploit wild fish stocks even more heavily in order to maintain their incomes constant when they are receiving less money per pound of fish.

3. A significant fraction of wild species, populations, and genetic diversity has already been lost, and at present rates a large fraction of what remains will be lost within the next half-century. Some species, such as big edible animals, or plants with edible fruits or good timber, are of obvious value to us. Among the many past societies that harmed themselves by exterminating such species were the Easter and Henderson Islanders whom we have discussed.

But biodiversity losses of small inedible species often provoke the response, "Who cares? Do you really care less for humans than for some lousy useless little fish or weed, like the snail darter or Furbish lousewort?" This response misses the point that the entire natural world is made up of wild species providing us for free with services that can be very expensive, and in many cases impossible, for us to supply ourselves. Elimination of lots of lousy little species regularly causes big harmful consequences for humans, just as does randomly knocking out many of the lousy little rivets holding together an airplane. The literally innumerable examples include: the role of earthworms in regenerating soil and maintaining its texture (one of the reasons that oxygen levels dropped inside the Biosphere 2 enclosure, harming its human inhabitants and crippling a colleague of mine, was a lack of appropriate earthworms, contributing to altered soil/atmosphere gas exchange); soil bacteria that fix the essential crop nutrient nitrogen, which otherwise we have to spend money to supply in fertilizers; bees and other insect pollinators (they pollinate our crops for free, whereas it's expensive for us to pollinate every crop flower by hand); birds and mammals that disperse wild fruits (foresters still haven't figured out how to grow from seed the most important commercial tree species of the Solomon Islands, whose seeds are naturally dispersed by fruit bats, which are becoming hunted out); elimination of whales, sharks, bears, wolves, and other top predators in the seas and on the land, changing the whole food chain beneath them; and wild plants and animals that decompose wastes and recycle nutrients, ultimately providing us with clean water and air.

4. Soils of farmlands used for growing crops are being carried away by water and wind erosion at rates between 10 and 40 times the rates of soil formation, and between 500 and 10,000 times soil erosion rates on forested land. Because those soil erosion rates are so much higher than soil formation rates, that means a net loss of soil. For instance, about half of the topsoil of Iowa, the state whose agriculture productivity is among the highest in the U.S., has been eroded in the last 150 years. On my most recent visit to Iowa, my hosts showed me a churchyard offering a dramatically visible example of those soil losses. A church was built there in the middle of farmland during the 19th century and has been maintained continuously as a church ever since, while the land around it was being farmed. As a result of soil being eroded much more rapidly from fields than from the churchyard, the yard now stands like a little island raised 10 feet above the surrounding sea of farmland.

Other types of soil damage caused by human agricultural practices include salinization, as discussed for Montana, China, and Australia in Chapters 1, 12, and 13; losses of soil fertility, because farming removes nutrients much more rapidly than they are restored by weathering of the underlying rock; and soil acidification in some areas, or its converse, alkalinization, in other areas. All of these types of harmful impacts have resulted in a fraction of the world's farmland variously estimated at between 20% and 80% having become severely damaged, during an era in which increasing human population has caused us to need more farmland rather than less farmland. Like deforestation, soil problems contributed to the collapses of all past societies discussed in this book.

The next three problems involve ceilings—on energy, freshwater, and photosynthetic capacity. In each case the ceiling is not hard and fixed but soft: we can obtain more of the needed resource, but at increasing costs.

5. The world's major energy sources, especially for industrial societies, are fossil fuels: oil, natural gas, and coal. While there has been much discussion about how many big oil and gas fields remain to be discovered, and while coal reserves are believed to be large, the prevalent view is that known and likely reserves of readily accessible oil and natural gas will last for a few more decades. This view should not be misinterpreted to mean that all of the oil and natural gas within the Earth will have been used up by then. Instead, further reserves will be deeper underground, dirtier, increasingly expensive to extract or process, or will involve higher environmental costs. Of course, fossil fuels are not our sole energy sources, and I shall consider problems raised by the alternatives below.

6. Most of the world's freshwater in rivers and lakes is already being utilized for irrigation, domestic and industrial water, and in situ uses such as boat transportation corridors, fisheries, and recreation. Rivers and lakes that are not already utilized are mostly far from major population centers and likely users, such as in Northwestern Australia, Siberia, and Iceland. Throughout the world, freshwater underground aquifers are being depleted at rates faster than they are being naturally replenished, so that they will eventually dwindle. Of course, freshwater can be made by desalinization of seawater, but that costs money and energy, as does pumping the resulting desalinized water inland for use. Hence desalinization, while it is useful locally, is too expensive to solve most of the world's water shortages. The Anasazi and Maya were among the past societies to be undone by water problems, while today over a billion people lack access to reliable safe drinking water.

7. It might at first seem that the supply of sunlight is infinite, so one might reason that the Earth's capacity to grow crops and wild plants is also infinite. Within the last 20 years, it has been appreciated that that is not the case, and that's not only because plants grow poorly in the world's Arctic regions and deserts unless one goes to the expense of supplying heat or water. More generally, the amount of solar energy fixed per acre by plant photosynthesis, hence plant growth per acre, depends on temperature and rainfall. At any given temperature and rainfall the plant growth that can be supported by the sunlight falling on an acre is limited by the geometry and biochemistry of plants, even if they take up the sunlight so efficiently that not a single photon of light passes through the plants unabsorbed to reach the ground. The first calculation of this photosynthetic ceiling, carried out in 1986, estimated that humans then already used (e.g., for crops, tree plantations, and golf courses) or diverted or wasted (e.g., light falling on concrete roads and buildings) about half of the Earth's photosynthetic capacity. Given the rate of increase of human population, and especially of population impact (see point 12 below), since 1986, we are projected to be utilizing most of the world's terrestrial photosynthetic capacity by the middle of this century. That is, most energy fixed from sunlight will be used for human purposes, and little will be left over to support the growth of natural plant communities, such as natural forests.

The next three problems involve harmful things that we generate or move around: toxic chemicals, alien species, and atmospheric gases.

8. The chemical industry and many other industries manufacture or release into the air, soil, oceans, lakes, and rivers many toxic chemicals, some of them "unnatural" and synthesized only by humans, others present naturally in tiny concentrations (e.g., mercury) or else synthesized by living things but synthesized and released by humans in quantities much larger than natural ones (e.g., hormones). The first of these toxic chemicals to achieve wide notice were insecticides, pesticides, and herbicides, whose effects on birds, fish, and other animals were publicized by Rachel Carson's 1962 book *Silent Spring*. Since then, it has been appreciated that the toxic effects of even greater significance for us humans are those on ourselves. The culprits include not only insecticides, pesticides, and herbicides, but also mercury and other metals, fire-retardant chemicals, refrigerator coolants, detergents, and components of plastics. We swallow them in our food and water, breathe them in our air, and absorb them through our skin. Often in very low concentrations, they variously cause birth defects, mental retardation, and temporary or permanent damage to our immune and reproductive systems. Some of them act as endocrine disruptors, i.e., they interfere with our reproductive systems by mimicking or blocking effects of our own sex hormones. They probably make the major contribution to the steep decline in sperm count in many human populations over the last several decades, and to the apparently increasing frequency with which couples are unable to conceive, even when one takes into account the increasing average age of marriage in many societies. In addition, deaths in the U.S. from air pollution alone (without considering soil and water pollution) are conservatively estimated at over 130,000 per year.

Many of these toxic chemicals are broken down in the environment only slowly (e.g., DDT and PCBs) or not at all (mercury), and they persist in the environment for long times before being washed out. Thus, cleanup costs of many polluted sites in the U.S. are measured in the billions of dollars (e.g., Love Canal, the Hudson River, Chesapeake Bay, the *Exxon Valdez* oil spill, and Montana copper mines). But pollution at those worst sites in the U.S. is mild compared to that in the former Soviet Union, China, and many Third World mines, whose cleanup costs no one even dares to think about.

9. The term "alien species" refers to species that we transfer, intentionally or inadvertently, from a place where they are native to another place where they are not native. Some alien species are obviously valuable to us as crops, domestic animals, and landscaping. But others devastate populations of native species with which they come in contact, either by preying on, parasitizing, infecting, or outcompeting them. The aliens cause these big effects because the native species with which they come in contact had no previous evolutionary experience of them and are unable to resist them (like human populations newly exposed to smallpox or AIDS). There are by now literally hundreds of cases in which alien species have caused one-time or annually recurring damages of hundreds of millions of dollars or even billions of dollars. Modern examples include Australia's rabbits and foxes, agricultural weeds like Spotted Knapweed and Leafy Spurge (Chapter 1), pests and pathogens of trees and crops and livestock (like the blights that wiped out American chestnut trees and devasted American elms), the water hyacinth that chokes waterways, the zebra mussels that choke power plants, and the lampreys that devastated the former commercial fisheries of the North American Great Lakes (Plates 30, 31). Ancient examples include the introduced rats that contributed to the extinction of Easter Island's palm tree by gnawing its nuts, and that ate the eggs and chicks of nesting birds on Easter, Henderson, and all other Pacific islands previously without rats.

10. Human activities produce gases that escape into the atmosphere, where they either damage the protective ozone layer (as do formerly widespread refrigerator coolants) or else act as greenhouse gases that absorb sunlight and thereby lead to global warming. The gases contributing to global warming include carbon dioxide from combustion and respiration, and methane from fermentation in the intestines of ruminant animals. Of course, there have always been natural fires and animal respiration producing carbon dioxide, and wild ruminant animals producing methane, but our burning of firewood and of fossil fuels has greatly increased the former, and our herds of cattle and of sheep have greatly increased the latter.

For many years, scientists debated the reality, cause, and extent of global warming: are world temperatures really historically high now, and, if so, by how much, and are humans the leading cause? Most knowledgeable scientists now agree that, despite year-to-year ups and downs of temperature that necessitate complicated analyses to extract warming trends, the atmosphere really has been undergoing an unusually rapid rise in temperature recently, and that human activities are the or a major cause. The remaining uncertainties mainly concern the future expected magnitude of the effect: e.g., whether average global temperatures will increase by "just" 1.5 degrees Centigrade or by 5 degrees Centigrade over the next century. Those numbers may not sound like a big deal, until one reflects that average global temperatures were "only" 5 degrees cooler at the height of the last Ice Age.

While one might at first think that we should welcome global warming on the grounds that warmer temperatures mean faster plant growth, it turns out that global warming will produce both winners and losers. Crop yields in cool areas with temperatures marginal for agriculture may indeed increase, while crop yields in already warm or dry areas may decrease. In Montana, California, and many other dry climates, the disappearance of mountain snowpacks will decrease the water available for domestic uses, and for irrigation that actually limits crop yields in those areas. The rise in global sea levels as a result of snow and ice melting poses dangers of flooding and coastal erosion for densely populated low-lying coastal plains and river deltas already barely above or even below sea level. The areas thereby threatened include much of the Netherlands, Bangladesh, and the seaboard of the eastern U.S., many low-lying Pacific islands, the deltas of the Nile and Mekong Rivers, and coastal and riverbank cities of the United Kingdom (e.g., London), India, Japan, and the Philippines. Global warming will also produce big secondary effects that are difficult to predict exactly in advance and that are likely to cause huge problems, such as further climate changes resulting from changes in ocean circulation resulting in turn from melting of the Arctic ice cap.

The remaining two problems involve the increase in human population:

11. The world's human population is growing. More people require more food, space, water, energy, and other resources. Rates and even the direction of human population change vary greatly around the world, with the highest rates of population growth (4% per year or higher) in some Third World countries, low rates of growth (1% per year or less) in some First World countries such as Italy and Japan, and negative rates of growth (i.e., decreasing populations) in countries facing major public health crises, such as Russia and AIDS-affected African countries. Everybody agrees that the world population is increasing, but that its annual percentage rate of increase is not as high as it was a decade or two ago. However, there is still disagreement about whether the world's population will stabilize at some value above its present level (double the present population?), and (if so) how many years (30 years? 50 years?) it will take for population to reach that level, or whether population will continue to grow.

There is long built-in momentum to human population growth because of what is termed the "demographic bulge" or "population momentum," i.e., a disproportionate number of children and young reproductive-age people in today's population, as a result of recent population growth. That is, suppose that every couple in the world decided tonight to limit themselves to two children, approximately the correct number of children to yield an unchanging population in the long run by exactly replacing their two parents who will eventually die (actually, 2.1 children when one considers childless couples and children who won't marry). The world's population would nevertheless continue to increase for about 70 years, because more people today are of reproductive age or entering reproductive age than are old and post-reproductive. The problem of human population growth has received much attention in recent decades and has given rise to movements such as Zero Population Growth, which aim to slow or halt the increase in the world's population.

12. What really counts is not the number of people alone, but their impact on the environment. If most of the world's 6 billion people today were in cryogenic storage and neither eating, breathing, nor metabolizing, that large population would cause no environmental problems. Instead, our numbers pose problems insofar as we consume resources and generate wastes. That per-capita impact—the resources consumed, and the wastes put out, by each person—varies greatly around the world, being highest in the First World and lowest in the Third World. On the average, each citizen of the U.S., western Europe, and Japan consumes 32 times more resources such as fossil fuels, and puts out 32 times more wastes, than do inhabitants of the Third World (Plate 35).

But low-impact people are becoming high-impact people for two reasons: rises in living standards in Third World countries whose inhabitants see and covet First World lifestyles; and immigration, both legal and illegal, of individual Third World inhabitants into the First World, driven by political, economic, and social problems at home. Immigration from low-impact countries is now the main contributor to the increasing populations of the U.S. and Europe. By the same token, the overwhelmingly most important human population problem for the world as a whole is not the high rate of population increase in Kenya, Rwanda, and some other poor Third World countries, although that certainly does pose a problem for Kenya and Rwanda themselves, and although that is the population problem most discussed. Instead, the biggest problem is the increase in total human impact, as the result of rising Third World living standards, and of Third World individuals moving to the First World and adopting First World living standards.

There are many "optimists" who argue that the world could support double its human population, and who consider only the increase in human numbers and not the average increase in per-capita impact. But I have not met anyone who seriously argues that the world could support 12 times its current impact, although an increase of that factor would result from all Third World inhabitants adopting First World living standards. (That factor of 12 is less than the factor of 32 that I mentioned in the preceding paragraph, because there are already First World inhabitants with high-impact lifestyles, although they are greatly outnumbered by Third World inhabitants.) Even if the people of China alone achieved a First World living standard while everyone else's living standard remained constant, that would double our human impact on the world (Chapter 12).

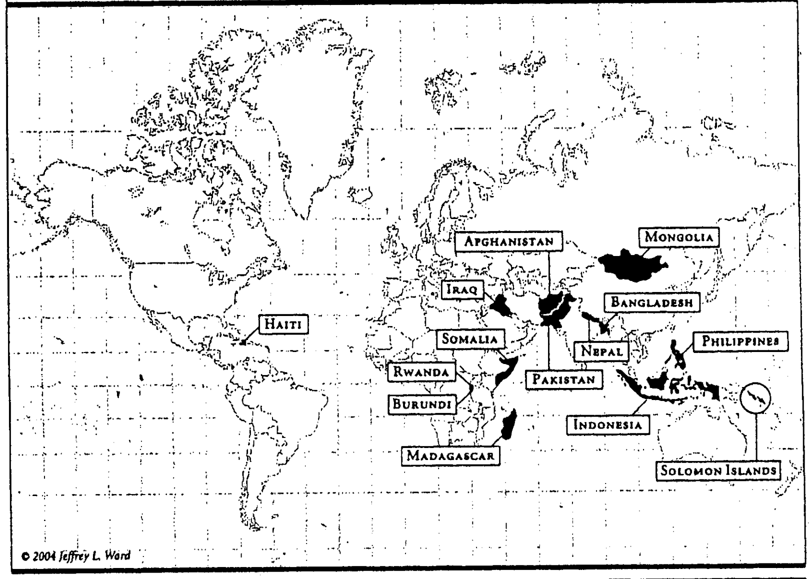
People in the Third World aspire to First World living standards. They develop that aspiration through watching television, seeing advertisements for First World consumer products sold in their countries, and observing First World visitors to their countries. Even in the most remote villages and refugee camps today, people know about the outside world. Third World citizens are encouraged in that aspiration by First World and United

Nations development agencies, which hold out to them the prospect of achieving their dream if they will only adopt the right policies, like balancing their national budgets, investing in education and infrastructure, and so on.

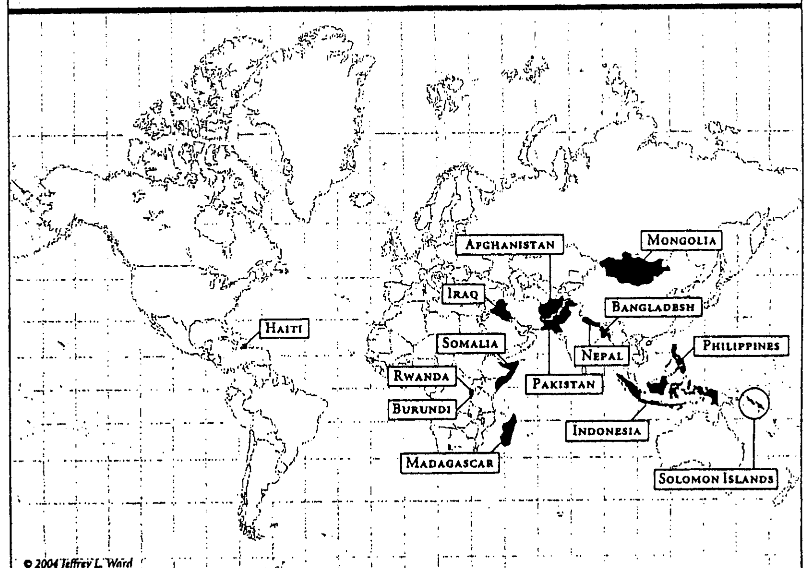
But no one at the U.N. or in First World governments is willing to acknowledge the dream's impossibility: the unsustainability of a world in which the Third World's large population were to reach and maintain current First World living standards. It is impossible for the First World to resolve that dilemma by blocking the Third World's efforts to catch up: South Korea, Malaysia, Singapore, Hong Kong, Taiwan, and Mauritius have already succeeded or are close to success; China and India are progressing rapidly by their own efforts; and the 15 rich Western European countries making up the European Union have just extended Union membership to 10 poorer countries of Eastern Europe, in effect thereby pledging to help those 10 countries catch up. Even if the human populations of the Third World did not exist, it would be impossible for the First World alone to maintain its present course, because it is not in a steady state but is depleting its own resources as well as those imported from the Third World. At present, it is untenable politically for First World leaders to propose to their own citizens that they lower their living standards, as measured by lower resource consumption and waste production rates. What will happen when it finally dawns on all those people in the Third World that current First World standards are unreachable for them, and that the First World refuses to abandon those standards for itself? Life is full of agonizing choices based on trade-offs, but that's the cruelest trade-off that we shall have to resolve: encouraging and helping all people to achieve a higher standard of living, without thereby undermining that standard through overstressing global resources.

I have described these 12 sets of problems as separate from each other. In fact, they are linked: one problem exacerbates another or makes its solution more difficult. For example, human population growth affects all 11 other problems: more people means more deforestation, more toxic chemicals, more demand for wild fish, etc. The energy problem is linked to other problems because use of fossil fuels for energy contributes heavily to greenhouse gases, the combating of soil fertility losses by using synthetic fertilizers requires energy to make the fertilizers, fossil fuel scarcity increases our interest in nuclear energy which poses potentially the biggest "toxic" problem of all in case of an accident, and fossil fuel scarcity also makes it more expensive to solve our freshwater problems by using energy to desalinize ocean

POLITICAL TROUBLE SPOTS OF THE MODERN WORLD



ENVIRONMENTAL TROUBLE SPOTS OF THE MODERN WORLD



water. Depletion of fisheries and other wild food sources puts more pressure on livestock, crops, and aquaculture to replace them, thereby leading to more topsoil losses and more eutrophication from agriculture and aquaculture. Problems of deforestation, water shortage, and soil degradation in the Third World foster wars there and drive legal asylum seekers and illegal emigrants to the First World from the Third World.

Our world society is presently on a non-sustainable course, and any of our 12 problems of non-sustainability that we have just summarized would suffice to limit our lifestyle within the next several decades. They are like time bombs with fuses of less than 50 years. For example, destruction of accessible lowland tropical rainforest outside national parks is already virtually complete in Peninsular Malaysia, will be complete at current rates within less than a decade in the Solomon Islands, the Philippines, on Sumatra, and on Sulawesi, and will be complete around the world except perhaps for parts of the Amazon Basin and Congo Basin within 25 years. At current rates, we shall have depleted or destroyed most of the world's remaining marine fisheries, depleted clean or cheap or readily accessible reserves of oil and natural gas, and approached the photosynthetic ceiling within a few decades. Global warming is projected to have reached a degree Centigrade or more, and a substantial fraction of the world's wild animal and plant species are projected to be endangered or past the point of no return, within half a century. People often ask, "What is the single most important environmental/population problem facing the world today?" A flip answer would be, "The single most important problem is our misguided focus on identifying the single most important problem!" That flip answer is essentially correct, because any of the dozen problems if unsolved would do us grave harm, and because they all interact with each other. If we solved 11 of the problems, but not the 12th, we would still be in trouble, whichever was the problem that remained unsolved. We have to solve them all.

Thus, because we are rapidly advancing along this non-sustainable course, the world's environmental problems *will* get resolved, in one way or another, within the lifetimes of the children and young adults alive today. The only question is whether they will become resolved in pleasant ways of our own choice, or in unpleasant ways not of our choice, such as warfare, genocide, starvation, disease epidemics, and collapses of societies. While all of those grim phenomena have been endemic to humanity throughout our history, their frequency increases with environmental degradation, population pressure, and the resulting poverty and political instability.

Examples of those unpleasant solutions to environmental and population problems abound in both the modern world and the ancient world. The examples include the recent genocides in Rwanda, Burundi, and the former Yugoslavia; war, civil war, or guerrilla war in the modern Sudan, Philippines, and Nepal, and in the ancient Maya homeland; cannibalism on prehistoric Easter Island and Mangareva and among the ancient Anasazi; starvation in many modern African countries and on prehistoric Easter Island; the AIDS epidemic already in Africa, and incipiently elsewhere; and the collapse of state government in modern Somalia, the Solomon Islands, and Haiti, and among the ancient Maya. An outcome less drastic than a worldwide collapse might "merely" be the spread of Rwanda-like or Haiti-like conditions to many more developing countries, while we First World inhabitants retain many of our First World amenities but face a future with which we are unhappy, beset by more chronic terrorism, wars, and disease outbreaks. But it is doubtful that the First World could retain its separate lifestyle in the face of desperate waves of immigrants fleeing from collapsing Third World countries, in numbers much larger than the current unstoppable influx. I'm reminded again of how I picture the end of Gardar Cathedral Farm and its splendid cattle barn on Greenland, overwhelmed by the influx of Norse from poorer farms where all the livestock had died or been eaten.

But before we let ourselves give way to this one-sidedly pessimistic scenario, let's examine further the problems facing us, and their complexities. This will bring us, I feel, to a position of cautious optimism.

To make the preceding discussion less abstract, I shall now illustrate how those dozen environmental problems affect lifestyles in the part of the world with which I am most familiar: the city of Los Angeles in Southern California, where I live. After growing up on the East Coast of the United States and living for several years in Europe, I first visited California in 1964. It immediately appealed to me, and I moved here in 1966.

Thus, I have seen how Southern California has changed over the last 39 years, mostly in ways that make it less appealing. By world standards, Southern California's environmental problems are relatively mild. Jokes of East Coast Americans to the contrary, this is not an area at imminent risk of a societal collapse. By world standards and even by U.S. standards, its human population is exceptionally rich and environmentally educated. Los Angeles is well known for some problems, especially its smog, but most of its environmental and population problems are modest or typical compared to those of other leading First World cities. How do those problems affect the lives of my fellow Angelenos and me?

The complaints voiced by virtually everybody in Los Angeles are those directly related to our growing and already high population: our incurable traffic jams; the very high price of housing (Plate 36), as a result of millions of people working in a few centers of employment, and only limited residential space near those centers; and, as a consequence, the long distances, of up to two hours and 60 miles one way, over which people commute daily in their cars between home and work. Los Angeles became the U.S. city with the worst traffic in 1987 and has remained so every year since then. Everyone recognizes that these problems have gotten worse within the last decade. They are now the biggest single factor hurting the ability of Los Angeles employers to attract and retain employees, and they affect our willingness to drive to events and to visit friends. For the 12-mile trip from my home to downtown Los Angeles or its airport, I now allow an hour and 15 minutes. The average Angeleno spends 368 hours per year, or the equivalent of fifteen 24-hour days, commuting to and from work, without considering time spent driving for other purposes (Plate 37).

No cure is even under serious discussion for these problems, which will only get worse. Such highway construction as is now proposed or under way aims only at smoothing a few of the tightest points of congestion and will be overwhelmed by the increasing number of cars. There is no end in sight to how much worse Los Angeles's problems of congestion will become, because millions of people put up with far worse traffic in other cities. For example, my friends in Bangkok, the capital of Thailand, now carry a portable small chemical toilet in their car because travel can be so prolonged and slow; they once set off to go out of town on a holiday weekend but gave up and returned home after 17 hours, when they had advanced only three miles through the traffic jam. While there are optimists who explain in the abstract why increased population will be good and how the world can accommodate it, I have never met an Angeleno (and very few people anywhere in the world) who personally expressed a desire for increased population in the area where he or she personally lived.

The contribution of Southern California to the ongoing increase in the world's average per-capita human impact, as a result of transfers of people from the Third World to the First World, has for years been the most explosive issue in California politics. California's population growth is accelerating, due almost entirely to immigration and to the large average family sizes of the immigrants after their arrival. The border between California and Mexico is long and impossible to patrol effectively against people from Central America seeking to immigrate here illegally in search of jobs and personal safety. Every month, one reads of would-be immigrants dying in the desert or being robbed or shot, but that does not deter them. Other illegal immigrants come from as far away as China and Central Asia, in ships that unload them just off the coast. California residents are of two minds about all those Third World immigrants seeking to come here to attain the First World lifestyle. On the one hand, our economy is utterly dependent on them to fill jobs in the service and construction industries and on farms. On the other hand, California residents complain that the immigrants compete with unemployed residents for many jobs, depress wages, and burden our already overcrowded hospitals and public education system. A measure (Proposition 187) on the 1994 state election ballot, overwhelmingly approved by voters but then gutted by the courts on constitutional grounds, would have deprived illegal immigrants of most state-funded benefits. No California resident or elected official has suggested a practical solution to the long-standing contradiction, reminiscent of Dominicans' attitude towards Haitians, between needing immigrants as workers and otherwise resenting their presence and their own needs.

Southern California is a leading contributor to the energy crisis. Our city's former network of electric streetcars collapsed in bankruptcies in the 1920s and 1930s, and the rights of way were bought up by automobile manufacturers and subdivided so as to make it impossible to rebuild the network (which competed with automobiles). Angelenos' preference for living in houses rather than in high-rise apartments, and the long distances and diverse routes over which employees working in any given district commute, have made it impossible to design systems of public transportation that would satisfy the needs of most residents. Hence Los Angelenos are dependent on motorcars.

Our high gas consumption, the mountains ringing much of the Los Angeles basin, and prevailing wind directions generate the smog problem that is our city's most notorious drawback (Plate 38). Despite progress in combating smog in recent decades, and despite seasonal variation (smog worst in the late summer and early autumn) and local variation (smog generally worse as one precedes inland), Los Angeles on the average continues to rank near the bottom of American cities for air quality. After years of improvement, our air quality has again been deteriorating in recent years. Another toxic problem that affects lifestyle and health is the spread of the disease-causing organism giardia in California's rivers and lakes over the last several

Unfortunately, the amounts of CFCs already in the atmosphere are sufficiently large, and their breakdown sufficiently slow, that they will continue to be present for many decades after the eventual end of all CFC production.

The other example involves the introduction of the motor vehicle. When I was a child in the 1940s, some of my teachers were old enough to remember the first decades of the 20th century, when motor vehicles were in the process of replacing horse-drawn carriages and trams on city streets of the United States. The two biggest immediate consequences experienced by urban Americans, my teachers recall, were that American cities became wonderfully cleaner and quieter. No longer were streets constantly polluted with horse manure and urine, and no longer was there the constant din of horse hoofs clicking on the pavement. Today, after a century's experience of cars and buses, it strikes us as ludicrous or inconceivable that anyone could praise them for being non-polluting and quiet. While no one is advocating a return to the horse as a solution to smog from engine emissions, the example does serve to illustrate the unanticipated negative side effects even of technologies that (unlike CFCs) we choose to retain.

"If we exhaust one resource, we can always switch to some other resource meeting the same need." Optimists who make such claims ignore the unforeseen difficulties and long transition times regularly involved. For instance, one area in which switching based on not-yet-perfected new technologies has repeatedly been touted as promising to solve a major environmental problem is automobiles. The current hope for breakthrough involves hydrogen cars and fuel cells, which are technologically in their infancy as applied to motor transport. Thus, there is not a track record justifying faith in the hydrogen-car solution to our fossil fuel problem. However, we do have a track record of a long series of other proposed new car technologies touted as breakthroughs, such as rotary engines and (most recently) electric cars, that aroused much discussion and even sales of production models, only to decline or disappear because of unforeseen problems.

Equally instructive is the automobile industry's recent development of fuel-efficient hybrid gas/electric cars, which have been enjoying increasing sales. However, it would be unfair for a believer in switching to mention hybrid cars without also mentioning the automobile industry's simultaneous development of SUVs, which have been outselling hybrids by a big margin and more than offsetting their fuel savings. The net result of these two technological breakthroughs has been that the fuel consumption and exhaust production of our national car fleet has been going up rather than down. Nobody has figured out a method to ensure that technology will yield only increasingly environment-friendly effects and products (e.g., hybrid cars), without also yielding environment-unfriendly effects and products (e.g., SUVs).

Another example of faith in switching and substitution is the hope that renewable energy sources, such as wind and solar energy, may solve the energy crisis. These technologies do indeed exist; many Californians now use solar energy to heat their swimming pools, and wind generators are already supplying about one-sixth of Denmark's energy needs. However, wind and solar energy have limited applicability because they can be used only at locations with reliable winds or sunlight. In addition, the recent history of technology shows that conversion times for adoption of major switches—e.g., from candles to oil lamps to gas lamps to electric lights for lighting, or from wood to coal to petroleum for energy—require several decades, because so many institutions and secondary technologies associated with the former technology have to be changed. It is indeed likely that energy sources other than fossil fuels will make increasing contributions to our motor transport and energy generation, but this is a long-term prospect. We'll also need to solve our fuel and energy problems for the next several decades, before new technologies become widespread. All too often, a focus by politicians or industries on the promise of hydrogen cars and wind energy for the distant future distracts attention from all the obvious measures needed right now to decrease driving and fuel consumption by existing cars, and to decrease consumption by fossil fuel generating plants.

"There really isn't a world food problem; there is already enough food; we only need to solve the transportation problem of distributing that food to places that need it." (The same thing could be said for energy.) Or else: *"The world's food problem is already being solved by the Green Revolution, with its new high-yield varieties of rice and other crops, or else it will be solved by genetically modified crops."* This argument notes two things: that First World citizens enjoy on the average greater per-capita food consumption than do Third World citizens; and that some First World countries, such as the United States, do or can produce more food than their citizens consume. If food consumption could be equalized over the world, or if surplus First World food could be exported to the Third World, might that alleviate Third World starvation?

The obvious flaw in the first half of this argument is that First World citizens show no interest in eating less, in order that Third World citizens could eat more. The flaw in the second half of the argument is that, while

First World countries are willing occasionally to export food to mitigate starvation occasioned by some crisis (such as a drought or war) in certain Third World countries, First World citizens have shown no interest in paying on a regular basis (via their tax dollars that support foreign aid and subsidies to farmers) to feed billions of Third World citizens on a chronic basis. If that did happen but without effective overseas family planning programs, which the U.S. government currently opposes on principle, the result would just be Malthus's dilemma, i.e., an increase in population proportional to an increase in available food. Population increase and Malthus's dilemma also contribute to explaining why, after decades of hope and money invested in the Green Revolution and high-yield varieties, starvation is still widespread in the world. All of these considerations mean that genetically modified (GM) food varieties by themselves are equally unlikely to solve the world's food problems (while world population supposedly remains stationary?). In addition, virtually all GM crop production at present is of just four crops (soybeans, corn, canola, and cotton) not eaten directly by humans but used for animal fodder, oil, or clothing, and grown in six temperate-zone countries or regions. Reasons are the strong consumer resistance to eating GM foods; and the cruel fact that companies developing GM crops can make money by selling their products to rich farmers in mostly affluent temperate-zone countries, but not by selling to poor farmers in developing tropical countries. Hence the companies have no interest in investing heavily to develop GM cassava, millet, or sorghum for Third World farmers.

"As measured by commonsense indicators such as human lifespan, health, and wealth (in economists' terms, per-capita gross national product or GNP), conditions have actually been getting better for many decades." Or: *"Just look around you: the grass is still green, there is plenty of food in the supermarkets, clean water still flows from the taps, and there is absolutely no sign of imminent collapse."* For affluent First World citizens, conditions have indeed been getting better, and public health measures have on the average lengthened lifespans in the Third World as well. But lifespan alone is not a sufficient indicator: billions of Third World citizens, constituting about 80% of the world's population, still live in poverty, near or below the starvation level. Even in the United States, an increasing fraction of the population is at the poverty level and lacks affordable medical care, and all proposals to change this situation (e.g., "Just provide everyone with health insurance paid by the government") have been politically unacceptable.

In addition, all of us know as individuals that we don't measure our economic well-being just by the present *size* of our bank accounts: we also look at our *direction* of cash flow. When you look at your bank statement and you see a positive $5,000 balance, you don't smile if you then realize that you have been experiencing a net cash drain of $200 per month for the last several years, and at that rate you have just two years and one month left before you have to file for bankruptcy. The same principle holds for our national economy, and for environmental and population trends. The prosperity that the First World enjoys at present is based on spending down its environmental capital in the bank (its capital non-renewable energy sources, fish stocks, topsoil, forests, etc.). Spending capital should not be misrepresented as making money. It makes no sense to be content with our present comfort when it is clear that we are currently on a non-sustainable course.

In fact, one of the main lessons to be learned from the collapses of the Maya, Anasazi, Easter Islanders, and those other past societies (as well as from the recent collapse of the Soviet Union) is that a society's steep decline may begin only a decade or two after the society reaches its peak numbers, wealth, and power. In that respect, the trajectories of the societies that we have discussed are unlike the usual courses of individual human lives, which decline in a prolonged senescence. The reason is simple: maximum population, wealth, resource consumption, and waste production mean maximum environmental impact, approaching the limit where impact outstrips resources. On reflection, it's no surprise that declines of societies tend to follow swiftly on their peaks.

"Look at how many times in the past the gloom-and-doom predictions of fearmongering environmentalists have proved wrong. Why should we believe them this time?" Yes, some predictions by environmentalists have proved incorrect, favorite examples of critics being a prediction made in 1980 by Paul Ehrlich, John Harte, and John Holdren about rises in prices of five metals, and predictions made in the Club of Rome forecast of 1972. But it is misleading to look selectively for environmentalist predictions that proved wrong, and not also to look for environmentalist predictions that proved right, or anti-environmentalist predictions that proved wrong. There is an abundance of errors of the latter sort: e.g., overly optimistic predictions that the Green Revolution would already have solved the world's hunger problems; the prediction of the economist Julian Simon that we could feed the world's population as it continues to grow for the next 7 billion years; and Simon's prediction "Copper can be made from other elements" and thus there is no risk of a copper shortage. As regards the first of Simon's two predictions, continuation of our current population growth rate would yield

Having lived for five years in Europe shortly after World War II, and then having married into a Polish family with a Japanese branch, I saw at first hand what can happen when parents take good care of their individual children but not of their children's future world. The parents of my Polish, German, Japanese, Russian, British, and Yugoslav friends also bought life insurance, made wills, and obsessed about the schooling of their children, as my wife and I have been doing more recently. Some of them were rich and would have had valuable property to will to their children. But they did not take good care of their children's world, and they blundered into the disaster of World War II. As a result, most of my European and Japanese friends born in the same year as I had their lives blighted in various ways, such as being orphaned, separated from one or both parents during their childhood, bombed out of their houses, deprived of schooling opportunities, deprived of their family estates, or raised by parents burdened with memories of war and concentration camps. The worst-case scenarios that today's children face if we too blunder about their world are different, but equally unpleasant.

This leaves us with two other common one-liners that we have not considered: *"There are big differences between modern societies and those past societies of Easter Islanders, Maya, and Anasazi who collapsed, so that we can't straightforwardly apply lessons from the past."* And: *"What can I, as an individual, do, when the world is really being shaped by unstoppable powerful juggernauts of governments and big businesses?"* In contrast to the previous one-liners, which upon examination can be quickly dismissed, these two concerns are valid and cannot be dismissed. I shall devote the remainder of this chapter to the former question, and a section of the Further Readings (pp. 555–59) to the latter question.

Are the parallels between the past and present sufficiently close that the collapses of the Easter Islanders, Henderson Islanders, Anasazi, Maya, and Greenland Norse could offer any lessons for the modern world? At first, a critic, noting the obvious differences, might be tempted to object, "It's ridiculous to suppose that the collapses of all those ancient peoples could have broad relevance today, especially to the modern U.S. Those ancients didn't enjoy the wonders of modern technology, which benefits us and which lets us solve problems by inventing new environment-friendly technologies. Those ancients had the misfortune to suffer from effects of climate change. They behaved stupidly and ruined their own environment by doing obviously dumb things, like cutting down their forests, overharvesting wild animal sources of their protein, watching their topsoil erode away, and building cities in dry areas likely to run short of water. They had foolish leaders who didn't have books and so couldn't learn from history, and who embroiled them in expensive and destabilizing wars, cared only about staying in power, and didn't pay attention to problems at home. They got overwhelmed by desperate starving immigrants, as one society after another collapsed, sending floods of economic refugees to tax the resources of the societies that weren't collapsing. In all those respects, we moderns are fundamentally different from those primitive ancients, and there is nothing that we could learn from them. Especially we in the U.S., the richest and most powerful country in the world today, with the most productive environment and wise leaders and strong loyal allies and only weak insignificant enemies—none of those bad things could possibly apply to us."

Yes, it's true that there are big differences between the situations of those past societies and our modern situation today. The most obvious difference is that there are far more people alive today, packing far more potent technology that impacts the environment, than in the past. Today we have over 6 billion people equipped with heavy metal machinery such as bulldozers and nuclear power, whereas the Easter Islanders had at most a few tens of thousands of people with stone chisels and human muscle power. Yet the Easter Islanders still managed to devastate their environment and bring their society to the point of collapse. That difference greatly increases, rather than decreases, the risks for us today.

A second big difference stems from globalization. Leaving out of this discussion for the moment the question of environmental problems within the First World itself, let's just ask whether the lessons from past collapses might apply anywhere in the Third World today. First ask some ivory-tower academic ecologist, who knows a lot about the environment but never reads a newspaper and has no interest in politics, to name the overseas countries facing some of the worst problems of environmental stress, overpopulation, or both. The ecologist would answer: "That's a no-brainer, it's obvious. Your list of environmentally stressed or overpopulated countries should surely include Afghanistan, Bangladesh, Burundi, Haiti, Indonesia, Iraq, Madagascar, Mongolia, Nepal, Pakistan, the Philippines, Rwanda, the Solomon Islands, and Somalia, plus others" (map, p. 497).

Then go ask a First World politician, who knows nothing and cares less about the environment and population problems, to name the world's worst trouble spots: countries where state government has already been overwhelmed and has collapsed, or is now at risk of collapsing, or has been wracked by recent civil wars; and countries that, as a result of those problems of their own, are also creating problems for us rich First World countries, which may end up having to provide foreign aid for them, or may face illegal immigrants from them, or may decide to provide them with military assistance to deal with rebellions and terrorists, or may even have to send in our own troops. The politician would answer, "That's a no-brainer, it's obvious. Your list of political trouble spots should surely include Afghanistan, Bangladesh, Burundi, Haiti, Indonesia, Iraq, Madagascar, Mongolia, Nepal, Pakistan, the Philippines, Rwanda, the Solomon Islands, and Somalia, plus others."

Surprise, surprise: the two lists are very similar. The connection between the two lists is transparent: it's the problems of the ancient Maya, Anasazi, and Easter Islanders playing out in the modern world. Today, just as in the past, countries that are environmentally stressed, overpopulated, or both become at risk of getting politically stressed, and of their governments collapsing. When people are desperate, undernourished, and without hope, they blame their governments, which they see as responsible for or unable to solve their problems. They try to emigrate at any cost. They fight each other over land. They kill each other. They start civil wars. They figure that they have nothing to lose, so they become terrorists, or they support or tolerate terrorism.

The results of these transparent connections are genocides such as the ones that already exploded in Bangladesh, Burundi, Indonesia, and Rwanda; civil wars or revolutions, as in most of the countries on the lists; calls for the dispatch of First World troops, as to Afghanistan, Haiti, Indonesia, Iraq, the Philippines, Rwanda, the Solomon Islands, and Somalia; the collapse of central government, as has already happened in Somalia and the Solomon Islands; and overwhelming poverty, as in all of the countries on these lists. Hence the best predictors of modern "state failures"—i.e., revolutions, violent regime change, collapse of authority, and genocide—prove to be measures of environmental and population pressure, such as high infant mortality, rapid population growth, a high percentage of the population in their late teens and 20s, and hordes of unemployed young men without job prospects and ripe for recruitment into militias. Those pressures create conflicts over shortages of land (as in Rwanda), water, forests, fish, oil, and minerals. They create not only chronic internal conflict, but also emigration of political and economic refugees, and wars between countries arising when authoritarian regimes attack neighboring nations in order to divert popular attention from internal stresses.

In short, it is not a question open for debate whether the collapses of past societies have modern parallels and offer any lessons to us. That question is settled, because such collapses have actually been happening recently, and others appear to be imminent. Instead, the real question is how many more countries will undergo them.

As for terrorists, you might object that many of the political murderers, suicide bombers, and 9/11 terrorists were educated and moneyed rather than uneducated and desperate. That's true, but they still depended on a desperate society for support and toleration. Any society has its murderous fanatics; the U.S. produced its own Timothy McVeigh and its Harvard-educated Theodore Kaczinski. But well-nourished societies offering good job prospects, like the U.S., Finland, and South Korea, don't offer broad support to their fanatics.

The problems of all these environmentally devastated, overpopulated distant countries become our own problems because of globalization. We are accustomed to thinking of globalization in terms of us rich advanced First Worlders sending our good things, such as the Internet and Coca-Cola to those poor backward Third Worlders. But globalization means nothin[g] more than improved worldwide communications, which can convey man[y] things in either direction; globalization is not restricted to good things carried only from the First to the Third World.

Among bad things transported from the First World to developin[g] countries, we already mentioned the millions of tons of electronic garbag[e] intentionally transported each year from industrialized nations to China. T[o] grasp the worldwide scale of unintentional garbage transport, consider th[e] garbage collected on the beaches of tiny Oeno and Ducie Atolls in th[e] Southeast Pacific Ocean (see map on p. 122): uninhabited atolls, withou[t] freshwater, rarely visited even by yachts, and among the world's most re[mote] bits of land, each over a hundred miles even from remote uninhabite[d] Henderson Island. Surveys there detected, for each linear yard of beach, o[n] the average one piece of garbage, which must have drifted from ships or els[e] from Asian and American countries on the Pacific Rim thousands of mil[es] distant. The commonest items proved to be plastic bags, buoys, glass an[d] plastic bottles (especially Suntory whiskey bottles from Japan), rope, shoe[s] and lightbulbs, along with oddities such as footballs, toy soldiers and ai[r]planes, bike pedals, and screwdrivers.

A more sinister example of bad things transported from the First World to developing countries is that the highest blood levels of toxic industrial chemicals and pesticides reported for any people in the world are for Eastern Greenland's and Siberia's Inuit people (Eskimos), who are also among the most remote from sites of chemical manufacture or heavy use. Their blood mercury levels are nevertheless in the range associated with acute mercury poisoning, while the levels of toxic PCBs (polychlorinated biphenyls) in Inuit mothers' breast milk fall in a range high enough to classify the milk as "hazardous waste." Effects on the women's babies include hearing loss, altered brain development, and suppressed immune function, hence high rates of ear and respiratory infections.

Why should levels of these poisonous chemicals from remote industrial nations of the Americas and Europe be higher in the Inuit than even in urban Americans and Europeans? It's because staples of the Inuit diet are whales, seals, and seabirds that eat fish, molluscs, and shrimp, and the chemicals become concentrated at each step as they pass up this food chain. All of us in the First World who occasionally consume seafood are also ingesting these chemicals, but in smaller amounts. (However, that doesn't mean that you will be safe if you stop eating seafood, because you now can't avoid ingesting such chemicals no matter what you eat.)

Still other bad impacts of the First World on the Third World include deforestation, Japan's imports of wood products currently being a leading cause of deforestation in the tropical Third World; and overfishing, due to fishing fleets of Japan, Korea, Taiwan and the heavily subsidized fleets of the European Union scouring the world's oceans. Conversely, people in the Third World can now, intentionally or unintentionally, send us their own bad things: their diseases like AIDS, SARS, cholera, and West Nile fever, carried inadvertently by passengers on transcontinental airplanes; unstoppable numbers of legal and illegal immigrants arriving by boat, truck, train, plane, and on foot; terrorists; and other consequences of their Third World problems. We in the U.S. are no longer the isolated Fortress America to which some of us aspired in the 1930s; instead, we are tightly and irreversibly connected to overseas countries. The U.S. is the world's leading importer nation: we import many necessities (especially oil and some rare metals) and many consumer products (cars and consumer electronics), as well as being the world's leading importer of investment capital. We are also the world's leading exporter, particularly of food and of our own manufactured products. Our own society opted long ago to become interlocked with the rest of the world.

That's why political instability anywhere in the world now affects us, our trade routes, and our overseas markets and suppliers. We are so dependent on the rest of the world that if, 30 years ago, you had asked a politician to name the countries most geopolitically irrelevant to our interests because of their being so remote, poor, and weak, the list would surely have begun with Afghanistan and Somalia, yet they subsequently became recognized as important enough to warrant our dispatching U.S. troops. Today the world no longer faces just the circumscribed risk of an Easter Island society or Maya homeland collapsing in isolation, without affecting the rest of the world. Instead, societies today are so interconnected that the risk we face is of a worldwide decline. That conclusion is familiar to any investor in stock markets: instability of the U.S. stock market, or the post-9/11 economic downturn in the U.S., affects overseas stock markets and economies as well, and vice versa. We in the U.S. (or else just affluent people in the U.S.) can no longer get away with advancing our own self-interests, at the expense of the interests of others.

A good example of a society minimizing such clashes of interest is the Netherlands, whose citizens have perhaps the world's highest level of environmental awareness and of membership in environmental organizations. I never understood why, until on a recent trip to the Netherlands I posed the question to three of my Dutch friends while driving through their countryside (Plates 39, 40). Their answer was one that I shall never forget:

"Just look around you here. All of this farmland that you see lies below sea level. One-fifth of the total area of the Netherlands is below sea level, as much as 22 feet below, because it used to be shallow bays, and we reclaimed it from the sea by surrounding the bays with dikes and then gradually pumping out the water. We have a saying, 'God created the Earth, but we Dutch created the Netherlands.' These reclaimed lands are called 'polders.' We began draining them nearly a thousand years ago. Today, we still have to keep pumping out the water that gradually seeps in. That's what our windmills used to be for, to drive the pumps to pump out the polders. Now we use steam, diesel, and electric pumps instead. In each polder there are lines of pumps, starting with those farthest from the sea, pumping the water in sequence until the last pump finally pumps it out into a river or the ocean. In the Netherlands, we have another expression, 'You have to be able to get along with your enemy, because he may be the person operating the neighboring pump in your polder.' And we're all down in the polders together. It's not the case that rich people live safely up on tops of the dikes while poor people live down in the polder bottoms below sea level. If the dikes and pumps fail, we'll all drown together. When a big storm and high tides swept inland over Zeeland Province on February 1, 1953, nearly 2,000 Dutch people, both rich and poor, drowned. We swore that we would never let that happen again, and the whole country paid for an extremely expensive set of tide barriers. If global warming causes polar ice melting and a world rise in sea level, the consequences will be more severe for the Netherlands than for any other country in the world, because so much of our land is already under sea level. That's why we Dutch are so aware of our environment. We've learned through our history that we're all living in the same polder, and that our survival depends on each other's survival."

That acknowledged interdependence of all segments of Dutch society contrasts with current trends in the United States, where wealthy people increasingly seek to insulate themselves from the rest of society, aspire to create their own separate virtual polders, use their own money to buy services for themselves privately, and vote against taxes that would extend those amenities as public services to everyone else. Those private amenities include living inside gated walled communities (Plate 36), relying on private security guards rather than on the police, sending one's children to well-funded private schools with small classes rather than to the underfunded crowded public schools, purchasing private health insurance or medical care, drinking bottled water instead of municipal water, and (in Southern California) paying to drive on toll roads competing with the jammed public freeways. Underlying such privatization is a misguided belief that the elite can remain unaffected by the problems of society around them: the attitude of those Greenland Norse chiefs who found that they had merely bought themselves the privilege of being the last to starve.

Throughout human history, most peoples have been connected to some other peoples, living together in small virtual polders. The Easter Islanders comprised a dozen clans, dividing their island polder into a dozen territories, and isolated from all other islands, but sharing among clans the Rano Raraku statue quarry, the Puna Pau pukao quarry, and a few obsidian quarries. As Easter Island society disintegrated, all the clans disintegrated together, but nobody else in the world knew about it, nor was anybody else affected. Southeast Polynesia's polder consisted of three interdependent islands, such that the decline of Mangareva's society was disastrous also for the Pitcairn and Henderson Islanders but for no one else. To the ancient Maya, their polder consisted at most of the Yucatán Peninsula and neighboring areas. When the Classic Maya cities collapsed in the southern Yucatán, refugees may have reached the northern Yucatán, but certainly not Florida. In contrast today our whole world has become one polder, such that events anywhere affect Americans. When distant Somalia collapsed, in went American troops; when the former Yugoslavia and Soviet Union collapsed, out went streams of refugees over all of Europe and the rest of the world; and when changed conditions of society, settlement, and lifestyle spread new diseases in Africa and Asia, those diseases moved over the globe. The whole world today is a self-contained and isolated unit, as Tikopia Island and Tokugawa Japan used to be. We need to realize, as did the Tikopians and Japanese, that there is no other island/other planet to which we can turn for help, or to which we can export our problems. Instead, we need to learn, as they did, to live within our means.

I introduced this section by acknowledging that there are important differences between the ancient world and the modern world. The differences that I then went on to mention—today's larger population and more potent destructive technology, and today's interconnectedness posing the risk of a global rather than a local collapse—may seem to suggest a pessimistic outlook. If the Easter Islanders couldn't solve their milder local problems in the past, how can the modern world hope to solve its big global problems?

People who get depressed at such thoughts often then ask me, "Jared, are you optimistic or pessimistic about the world's future?" I answer, "I'm a cautious optimist." By that, I mean that, on the one hand, I acknowledge the seriousness of the problems facing us. If we don't make a determined effort to solve them, and if we don't succeed at that effort, the world as a whole within the next few decades will face a declining standard of living, or perhaps something worse. That's the reason why I decided to devote most of my career efforts at this stage of my life to convincing people that our problems have to be taken seriously and won't go away otherwise. On the other hand, we shall be able to solve our problems—if we choose to do so. That's why my wife and I did decide to have children 17 years ago: because we did see grounds for hope.

One basis for hope is that, realistically, we are not beset by insoluble problems. While we do face big risks, the most serious ones are not ones beyond our control, like a possible collision with an asteroid of a size that hits the Earth every hundred million years or so. Instead, they are ones that we are generating ourselves. Because we are the cause of our environmental problems, we are the ones in control of them, and we can choose or not choose to stop causing them and start solving them. The future is up for grabs, lying in our own hands. We don't need new technologies to solve our problems; while new technologies can make some contribution, for the most part we "just" need the political will to apply solutions already available. Of course, that's a big "just." But many societies did find the necessary political will in the past. Our modern societies have already found the will to solve some of our problems, and to achieve partial solutions to others.

Another basis for hope is the increasing diffusion of environmental thinking among the public around the world. While such thinking has been with us for a long time, its spread has accelerated, especially since the 1962 publication of *Silent Spring*. The environmental movement has been gaining adherents at an increasing rate, and they act through a growing diversity of increasingly effective organizations, not only in the United States and Europe but also in the Dominican Republic and other developing countries. At the same time as the environmental movement is gaining strength at an increasing rate, so too are the threats to our environment. That's why I referred earlier in this book to our situation as that of being in an exponentially accelerating horse race of unknown outcome. It's neither impossible, nor is it assured, that our preferred horse will win the race.

What are the choices that we must make if we are now to succeed, and not to fail? There are many specific choices, of which I discuss examples in the Further Readings section, that any of us can make as individuals. For our society as a whole, the past societies that we have examined in this book suggest broader lessons. Two types of choices seem to me to have been crucial in tipping their outcomes towards success or failure: long-term planning, and willingness to reconsider core values. On reflection, we can also recognize the crucial role of these same two choices for the outcomes of our individual lives.

One of those choices has depended on the courage to practice long-term thinking, and to make bold, courageous, anticipatory decisions at a time when problems have become perceptible but before they have reached crisis proportions. This type of decision-making is the opposite of the short-term reactive decision-making that too often characterizes our elected politicians—the thinking that my politically well-connected friend decried as "90-day thinking," i.e., focusing only on issues likely to blow up in a crisis within the next 90 days. Set against the many depressing bad examples of such short-term decision-making are the encouraging examples of courageous long-term thinking in the past, and in the contemporary world of NGOs, business, and government. Among past societies faced with the prospect of ruinous deforestation, Easter Island and Mangareva chiefs succumbed to their immediate concerns, but Tokugawa shoguns, Inca emperors, New Guinea highlanders, and 16th-century German landowners adopted a long view and reafforested. China's leaders similarly promoted reafforestation in recent decades and banned logging of native forests in 1998. Today, many NGOs exist specifically for the purpose of promoting sane long-term environmental policies. In the business world the American corporations that remain successful for long times (e.g., Procter and Gamble) are ones that don't wait for a crisis to force them to reexamine their policies, but that instead look for problems on the horizon and act before there is a crisis. I already mentioned Royal Dutch Shell Oil Company as having an office devoted just to envisioning scenarios decades off in the future.

Courageous, successful, long-term planning also characterizes some governments and some political leaders, some of the time. Over the last 30 years a sustained effort by the U.S. government has reduced levels of the six major air pollutants nationally by 25%, even though our energy consumption and population increased by 40% and our vehicle miles driven increased by 150% during those same decades. The governments of Malaysia, Singapore, Taiwan, and Mauritius all recognized that their long-term economic well-being required big investments in public health to prevent tropical diseases from sapping their economies; those investments proved to be a key to those countries' spectacular recent economic growth. Of the former two halves of the overpopulated nation of Pakistan, the eastern half (independent since 1971 as Bangladesh) adopted effective family planning measures to reduce its rate of population growth, while the western half (still known as Pakistan) did not and is now the world's sixth most populous country. Indonesia's former environmental minister Emil Salim, and the Dominican Republic's former president Joaquín Balaguer, exemplify government leaders whose concern about chronic environmental dangers made a big impact on their countries. All of these examples of courageous long-term thinking in both the public sector and the private sector contribute to my hope.

The other crucial choice illuminated by the past involves the courage to make painful decisions about values. Which of the values that formerly served a society well can continue to be maintained under new changed circumstances? Which of those treasured values must instead be jettisoned and replaced with different approaches? The Greenland Norse refused to jettison part of their identity as a European, Christian, pastoral society, and they died as a result. In contrast, Tikopia Islanders did have the courage to eliminate their ecologically destructive pigs, even though pigs are the sole large domestic animal and a principal status symbol of Melanesian societies. Australia is now in the process of reappraising its identity as a British agricultural society. The Icelanders and many traditional caste societies of India in the past, and Montana ranchers dependent on irrigation in recent times, did reach agreement to subordinate their individual rights to group interests. They thereby succeeded in managing shared resources and avoiding the tragedy of the commons that has befallen so many other groups. The government of China restricted the traditional freedom of individual reproductive choice, rather than let population problems spiral out of control. The people of Finland, faced with an ultimatum by their vastly more powerful Russian neighbor in 1939, chose to value their freedom over their lives, fought with a courage that astonished the world, and won their gamble, even while losing the war. While I was living in Britain from 1958 to 1962, the British people were coming to terms with the outdatedness of cherished long-held values based on Britain's former role as the world's dominant political, economic, and naval power. The French, Germans, and other European countries have advanced even further in subordinating to the European Union their national sovereignties for which they used to fight so dearly.

All of these past and recent reappraisals of values that I have just mentioned were achieved despite being agonizingly difficult. Hence they also contribute to my hope. They may inspire modern First World citizens with the courage to make the most fundamental reappraisal now facing us: how much of our traditional consumer values and First World living standard can we afford to retain? I already mentioned the seeming political impossibility of inducing First World citizens to lower their impact on the world. But the alternative, of continuing our current impact, is more impossible. This dilemma reminds me of Winston Churchill's response to criticisms of democracy: "It has been said that Democracy is the worst form of government except all those other forms that have been tried from time to time." In that spirit, a lower-impact society is the most impossible scenario for our future—except for all other conceivable scenarios.

Actually, while it won't be easier to reduce our impact, it won't be impossible either. Remember that impact is the product of two factors: population, multiplied times impact per person. As for the first of those two factors, population growth has recently declined drastically in all First World countries, and in many Third World countries as well—including China, Indonesia, and Bangladesh, with the world's largest, fourth largest, and ninth largest populations respectively. Intrinsic population growth in

Japan and Italy is already below the replacement rate, such that their existing populations (i.e., not counting immigrants) will soon begin shrinking. As for impact per person, the world would not even have to decrease its current consumption rates of timber products or of seafood: those rates could be sustained or even increased, if the world's forests and fisheries were properly managed.

My remaining cause for hope is another consequence of the globalized modern world's interconnectedness. Past societies lacked archaeologists and television. While the Easter Islanders were busy deforesting the highlands of their overpopulated island for agricultural plantations in the 1400s, they had no way of knowing that, thousands of miles to the east and west at the same time, Greenland Norse society and the Khmer Empire were simultaneously in terminal decline, while the Anasazi had collapsed a few centuries earlier, Classic Maya society a few more centuries before that, and Mycenean Greece 2,000 years before that. Today, though, we turn on our television sets or radios or pick up our newspapers, and we see, hear, or read about what happened in Somalia or Afghanistan a few hours earlier. Our television documentaries and books show us in graphic detail why the Easter Islanders, Classic Maya, and other past societies collapsed. Thus, we have the opportunity to learn from the mistakes of distant peoples and past peoples. That's an opportunity that no past society enjoyed to such a degree. My hope in writing this book has been that enough people will choose to profit from that opportunity to make a difference.