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Climate and Civilization: A Short History

Beginning in 1816, "the year without a summer," widespread crop failures led to food riots in nearly every country of Europe, producing a revolutionary fervor that swept the continent for three years. In France, for example, the existing government fell and the conservative Duc de Richelieu was asked to form a new one. Everywhere governments struggled to maintain social order as an unprecedented crime epidemic surged in the cities. The Swiss were stunned by the wave of criminal activity. Even the number of suicides increased dramatically, along with executions of women for infanticide.

Historians describe "swarms of beggars" clogging the roads and beseeching passersby. In a typical account, a traveler through Burgundy in 1817 reported that "beggars, very numerous yesterday, have increased greatly; at every stage a crowd of women and children and of old men gather round the carriage." Another observer, who was visiting Burgundy from the British Isles, added that the number, while large, was "by no means as many as besieged the traveller in Ireland." In Switzerland, eyewitnesses said the numbers of beggars thronging every highway were so huge as to resemble armies. They had desperation in their eyes and, in the words of a local chronicler, Ruprecht Zollikofer, "the paleness of death in their cheeks."

As fears of revolution mounted in several countries, military force was used to control the growing crowds demanding food. An unprecedented wave of arson began to strike in almost every country. Ominously, the first anti-Semitic riots in the history of modern Germany broke out in the Bavarian town of Wurzburg in the summer of 1819 and, after famine and revolutionary fervor had exacerbated tensions and resentments, quickly spread throughout Germany and as far north as Amsterdam and Copenhagen.

Europe was just recovering from the Napoleonic Wars and was experiencing many changes. But although no one realized it at the time, the proximate cause of this suffering and social unrest was a change in the composition of the global atmosphere following an unusually large series of eruptions of the Tambora volcano, on the island of Sumbawa, Indonesia, in the spring of 1815. Scientists estimate that 10,000 people were killed in the initial eruption and approximately 82,000 more died of starvation and disease in the following months. However, the worst effects on the rest of the world were not felt until a year later, by which time the dust ejected into the sky had spread throughout the atmosphere and had begun to dramatically reduce the amount of sunlight reaching the surface of the earth and to force temperatures down.

In New England, there was widespread snow in June of 1816 and frost throughout the summer. The *Old Farmer's Almanac* became popular when a typographical error predicted snow in July 1816 — and it happened. From Ireland across England to the Baltics, rain fell almost continuously from May to October. The disruption of reliable climate patterns had carefully documented social consequences: failed harvests, food riots, and the near-collapse of society throughout the British Isles and Europe. The historian John D. Post has called it "the last great subsistence crisis in the Western world."

The climate changes precipitating this crisis appear to have lasted fewer than three years, perhaps because much of what is blown into the atmosphere by volcanoes falls back out of the atmosphere in a relatively short period of time. That is why the effects of even the largest volcanic eruptions, while often global, typically do not persist for more than one to two years. The eruption of Mount Pinatubo in the Philippines in 1991, for example, had a significant but short-lived global impact, cooling the earth and temporarily masking the much more powerful warming caused by human civilization, and temporarily accelerating ozone depletion.

Nevertheless, the large volcanic eruptions recorded throughout history are instructive about longer-term changes in three important ways. First, they demonstrate how dependent our civilization is on stable climate conditions of the kind we have enjoyed for most of the last 10,000 years. Second, they show how tragedies striking one part of the world can be caused by climate changes originating in an entirely different part of the world. And third, they suggest the devastating consequences of a comparatively sudden and massive manmade change in the global climate pattern.

Because the ancients knew little about the world beyond their own borders, they had no way of comprehending the cause-and-effect relationships between volcanoes on the other side of the world and dramatic climate changes in their own lands. Recently, however, detailed climate records from the ice cores in Greenland and Antarctica have determined the dates of major volcanic eruptions throughout antiquity, and scientists have correlated these records with evidence from tree rings, geology and archaeology, and a meticulous analysis of documents from ancient civilizations concerning climate history. The Chinese, in particular, have preserved records dating back as far as thirty-six centuries.

Thus, records from tree rings and ice cores, along with documents left by Chinese historians, have now been combined to describe the devastating effects of one of the largest volcanic eruptions in recorded history: Santorini, seventy miles north of Crete, exploded around 1600 B.C. with a force a hundred times larger than that of the well-known eruption of Krakatoa in 1883. The climate effects of Santorini most likely contributed to the sudden disappearance not long afterward of the Minoan civilization, which had dominated the eastern Mediterranean for a thousand years during the Bronze Age. (Some historians believe that the disappearance of the Minoans was the basis of Plato's description of the loss in a single day of the fabled Atlantis.)

Five centuries later, sometime between 1150 and 1136 B.C., the Hekla 3 volcano, in Iceland, blew millions of tons of dust and particulates into the atmosphere. Contemporaneously, according to a primitive Chinese script preserved on dry bamboo strips, "it rained dust at Po." According to another Chinese writer, "For ten days the sky rained ashes. The rain was gray." And according to

still a third, "it snowed in the sixth month and the snow was over a foot deep . . . frosts killed the five cereal crops . . . fiber crops did not mature . . . and there was heavy rainfall." This time, archaeologists found evidence of devastating consequences in the Western Hemisphere as well. Scottish archaeologists assert that at this same time, 90 percent of the population of Scotland and northern England disappeared. Moreover, an analysis of soil samples indicates that extremely heavy precipitation and frigid temperatures forced the temporary cessation of agriculture.

Sometime around 209 B.C. there was a huge eruption, believed to be from a volcano in Iceland, which left its evidence deep in the annual layers of snow and ice covering Greenland and the frost-damaged rings of Irish oaks. Two years later, according to the Chinese historian Szu-ma Ch'ien, "the harvest had failed" for reasons no one understood. And two years after that, the Chinese historian Pan Ku wrote in the *Han shu*, "a great famine" killed more than half the population. "People ate each other." The emperor, he wrote, lifted the legal prohibitions against the sale of children. It was during this period, according to the Chinese *Table of Dynastic Records*, in 208 B.C., that "stars were not seen for three months."

The famous eruption of Mount Etna in Sicily in 42 B.C. was chronicled by Roman poets but only recently linked with catastrophic climate changes affecting China by historians studying newly translated texts. Pan Ku described how the sun was "veiled and indistinct" and how harvests failed, sending grain prices up more than 1,000 percent. He noted an edict issued in the summer that said: "The multitudes work hard plowing and weeding, without producing results. They suffer from famine and there is no way they can be saved."

Surprisingly, small climate changes caused by volcanic eruptions may also have played a major role in one of the modern era's seminal events, the French Revolution. In his groundbreaking study of the history of climate, *Times of Feast, Times of Famine*, Emmanuel Le Roy Ladurie describes in meticulous detail the disastrous crop failures and poor harvests in France during the six years immediately preceding the Revolution of 1789, culminating in the bitter winter of 1788–89 and one of the coldest Mays in

history before the storming of the Bastille. That year the wine harvest was "an utter failure."

As it happens, one of the best available reports on the weather in those years comes from Benjamin Franklin, who had been in France since December of 1776. In May 1784 he wrote,

> During several summer months of the year 1783, when the effects of the sun's rays to heat the earth in these northern regions should have been greatest, there existed a constant fog over all of Europe and parts of North America. This fog was of a permanent nature; it was dry, and the rays of the sun seemed to have little effect in dissipating it as they easily do a moist fog rising from water. They were, indeed, rendered so faint in passing through it that, when collected in the focus of a burning glass they would scarcely kindle brown paper. Of course their summer effect in heating the earth was exceedingly diminished. Hence the surface was nearly frozen. Hence the snow remained on it unmelted, and received continual additions. . . . Perhaps the winter of 1783–84 was more severe than any that happened for many years.

Franklin shrewdly speculated that "the cause of this universal fog is not yet ascertained. . . . Whether it was the vast quantity of smoke, long continuing to issue during the summer from Hekla in Iceland, and that other volcano [Skaptar Jokul] which rose out of the sea near the island, which smoke might be spread by various winds, is yet uncertain." What he could not have known was that in addition to the Icelandic eruptions, later that same year the Asama volcano in Japan registered one of the most violent eruptions in history and in all likelihood was the main source of the unusually cold years of the middle 1780s, contributing to the crop failures and social unrest preceding the French Revolution, which decisively reshaped the modern world.

The role of climate in shaping human history is, of course, extremely complex, and climate historians often debate the degree to which climate should be assigned a deterministic role. It always interacts with the social, political, and economic factors that dominate our traditional approach to history, but some climate upheavals seem from circumstantial evidence to be extremely significant, even dominant, factors in shaping public moods and attitudes immediately before political upheavals. Just as the enormous climate-induced suffering from 1816 through 1819 obviously contributed to the concurrent political unrest in Europe, it seems clear that the climate-induced suffering in France from 1783 through 1789 played a major role in worsening the political mood in which the French Revolution took place. However, it seems just as clear that climate changes were only one of many causes leading to these events. And just because climate has been largely ignored in standard histories does not mean that it should suddenly be given an exclusive explanatory role.

Nevertheless, the effects of climate change on the political and social stability of civilization are powerful, and as we consider the possibility that humankind is now changing the climate of the entire globe to a degree far greater — and faster — than anything that has occurred in human history, we would do well to examine some of the lessons provided by nature.

In addition to helping cause famine and political unrest, one of the most dramatic effects of climate change on civilization has been massive migrations from one geographic area to another. In fact, one of the greatest migrations in history — the one that introduced human beings into North America and then South America — came about as a direct result of climate change. During the last Ice Age, roughly 20,000 years ago, when vast amounts of seawater were frozen into ice, sea level was about three hundred feet lower than it is today. Large areas of those parts of the ocean bottom we call the continental shelf were exposed as dry land, and shallow ocean straits, like the Bering Strait and the Gulf of Carpentaria, were instead land bridges. These bridges served as the migratory routes for the people now known as aborigines in Australia and the Asiatic nomads now known in North America as Native Americans and in South America as Indians or indigenous people. As the glaciers retreated, the sea level rose again some 10,000 years ago, stranding the Native Americans and aborigines on their new continents. At the same time, as temperatures climbed, the global climate settled into the pattern that it has roughly maintained ever since.

In fact, the Ice Age that so profoundly affected the Americas shaped the very roots of all human civilization. The cave paintings that represent the first known graphic communication by human

beings appeared 17,000 years ago, when people sought refuge and warmth during the worst and coldest millennia.

Indeed, the succession of ice ages and warming interglacial periods between 1 million and 40,000 years ago is believed by most historians to have provided the impetus for the development of rudimentary social organizations. The archaeological and anthropological records indicate that each time the ice retreated, the primitive peoples of the Eurasian landmass grew more populous and their culture more advanced.

Between 8000 and 7000 B.C., when favorable climate conditions prevailed as the glaciers were melting into their present retreats, the area we know as Mesopotamia saw the creation of agricultural surpluses. And the trading of those surpluses is believed to have been responsible for the invention of money, the first communities to use brick and stone architecture, and the development of a broad range of arts and crafts. Jericho, for example, the oldest known city, was founded in this period, while Europe was just beginning to recover from the Ice Age.

Later, smaller but still significant climate fluctuations continued to shape the beginning of more complex social forms. Some historians believe that the first appearance of highly organized societies in the fertile river valleys of the Tigris, the Euphrates, and the Nile was stimulated by a major climate transition some 3,000 years ago. A new climate pattern — characterized by drought during most of the year and annual flooding — forced communities to cluster in the river valleys. The challenge of containing and distributing the floodwaters for irrigation, storing the annual harvests, and distributing food supplies required that many basic mechanisms of human civilization be put in place. In the Bible, Joseph's warning to Pharaoh to prepare for seven lean years following seven fat years reflects the new awareness of humankind of its vulnerability to changes in the weather patterns. In turn, when Pharaoh appoints Joseph, who interpreted the ecological meaning of Pharaoh's dream, to oversee preparations for the lean years, his decision reflects the assertion by humankind of the power to anticipate and prepare for climate fluctuations.

But it's now becoming clear that climate is even more basic to the development of humankind. Anthropologists, evolutionary biologists, and climate specialists — including Elisabeth S. Vrba, Frederick E. Grine, Richard G. Klein, and David Pilbeam — have recently combined the history of climate changes with the anthropological evidence to produce a new consensus — that human evolution itself was shaped by dramatic transitions in global climate patterns during the last 6 million years. The science writer William K. Stevens describes "an outpouring of analysis" and says that "scientists are sketching out the influential roles played by climate and ecology in shaping human evolution."

The major global cooling period that gradually took place more than 5 million years ago corresponds with the appearance of the first hominids, called australopithecines. It happened because — in the view of many scientists — at least one species of tree-dwelling ape was able to adapt to the disappearance of its forest habitat by learning to forage on the ground and walk on two legs, leaving the hands — which had evolved to grasp tree limbs — free to hold and carry food and objects, some of which later became tools.

A second global cooling period about 2.5 million years ago, more extreme and abrupt, explains — in this view — the "pulse" or evolutionary stimulus that produced a new, advanced branch of robust australopithecines. They were eventually displaced by the genus *Homo,* which appeared about 100,000 years ago after four relatively short (in geologic terms) but extreme ice ages — immediately before the last Ice Age. This period of incredible ecological change put a premium on the larger brains needed to adapt to rapidly changing climate conditions. The new discoveries relating the emergence of *Homo sapiens* to global climate changes have solved one of the mysteries in the human story by providing, at least in ecological terms, the missing link in the history of evolution. Then, 40,000 years ago, the so-called cultural explosion of tools and jewelry may have coincided with an unusually warm millennium in Europe.

But within this larger glacial and interglacial pattern there have been significant fluctuations. While they are quite small compared to either an ice age or to the manmade warming period now in prospect, they have nevertheless been large enough to have dramatic effects on civilization.

For example, a climate shift known as the subatlantic deterioration, from 500 to 400 B.C., led to a change in wind and moisture distribution and lower temperatures across Europe that are generally credited with bringing about the end of the northern Bronze Age and spurring the Germanic invasions of southeastern Europe from Scandinavia. Less than a century later, in what may be more than a coincidental continuation of the southeastern thrust of migration, the Macedonians conquered Greece. It was in the very next generation, as the climate began to warm all over the world in roughly 300 B.C., that Alexander the Great conquered the "known world" and spread Greek civilization throughout the Mediterranean and beyond.

This same period of relative warming cleared the Alpine passes separating Italy from the rest of Europe and corresponded to the awakening of Rome's imperial ambition. Moreover, the simultaneous clearing of mountain passes in Asia led to the expansion of Chinese civilization and the opening of the Silk Route. Some 750 years later, the end of this warming period corresponded to the final years of the Roman Empire. To the many explanations of why Rome fell, climate historians add the sudden shift in global climate patterns between A.D. 450 and 500 that led to a prolonged freezing drought in central Europe which, they suspect, may have stimulated the corresponding onset of the massive migrations that eventually became known as the barbarian invasions.

In sixteenth-century India, the grand city of Fatepur Sikri was completely abandoned just after its completion when a sudden change in the monsoon pattern deprived it of water. The people who had planned to live there were forced to go elsewhere, merely repeating a pattern already established in the Indian subcontinent. In fact, one of the first examples of an empire collapsing largely as a result of climate changes occurred a few hundred miles west of Fatepur Sikri some twenty-four centuries earlier. For a thousand years before 1900 B.C., the great Indus civilization flourished in what is now northwestern India and Pakistan. Then, suddenly, at a time when climate historians describe a southward expansion of cold polar air into northern Canada, the climate patterns changed, and what once were large cities and settlements were buried under the sand dunes of the Rajputana Desert, forcing the people to move

elsewhere. Similarly, the collapse of the Mali civilization of West Africa in the fourteenth century is among other societal declines that climate historians now suspect may have been caused by sudden shifts in climate patterns.

And then there is the mystery of Mycenae, the elaborate civilization derived from Minoan culture that was the home of King Agamemnon in Homer's epics and that — after dominating the Aegean for more than two centuries — abruptly disappeared soon after 1200 B.C. Historians and archaeologists have speculated that there was an invasion by peoples from farther north, and there is evidence that many Mycenaeans fled to the south and east, but the suddenness of the collapse has remained a puzzle. However, recent climate analyses have added a provocative piece of evidence: just before the disappearance of the Mycenaean civilization, a dramatic shift in the prevailing wind and moisture patterns throughout Europe, the Mediterranean, North Africa, and the Middle East suddenly diverted the regular rainfall on which Mycenae had always depended. The new pattern still brought moisture from the west, across the Mediterranean, but from farther south and at such low altitudes that the rain fell on the western side of the mountains at the edge of the Peloponnesian peninsula. This triggered a prolonged and unrelenting drought in Mycenae, on the eastern side of the mountains, drying up wells and streams, killing crops, and eventually forcing the people to leave.

Some climate historians also believe that this same set of changes in the Mediterranean weather patterns was largely responsible for catastrophic flooding episodes in the Hungarian plain, which led in turn to the great eruption of Bronze Age peoples across the Bosporous from the Balkans. These mass migrations by the Phrygians and other peoples from what is now Armenia caused the collapse of the Hittite civilization of Asia Minor around 1200 B.C., triggering politically and militarily disruptive mass migrations through Cyprus, Syria, Palestine, and Egypt, echoes of which are found throughout the Old Testament. In fact, the same migration from the Hungarian plain sent another group of people to the southwest, through the mountain passes into Italy, where they became known as the Etruscans and planted the seeds of what in time became the Roman civilization.

In the Western Hemisphere, a new analysis of global climate records may shed light on the mysterious rise and fall of the classic Mayan civilization, which began to flourish around A.D. 250–300 in what we call Yucatán, southern Mexico, and Central America. For reasons that are still unclear and that provoke vigorous debate among archaeologists and historians, the Mayan culture suddenly collapsed around 950. The Mayans had built fantastic cities, with elaborate underground reservoirs and giant structures as large as any in the world at that time. These included sophisticated observatories from which their astronomers calculated the precise length of the solar year and the lunar month. They knew the precise orbital path of the planet Venus and were even able to predict eclipses. Their mathematicians independently discovered the mathematical concept of zero. Yet this enormously sophisticated culture suddenly ended. Its cities were mysteriously abandoned, not destroyed. There was an abrupt end to the manufacture of fine pottery and carvings, the creation of monuments, temples, records, calendars, and writing, and the rapid depopulation of the ceremonial centers and the countryside — all within fifty to a hundred years. Scientists have produced a variety of theories — from fratricidal violence and societal breakdown to an unknown invasion to hurricanes, earthquakes, soil exhaustion, water loss, savanna grass competition, and overpopulation.

What no study has suggested is that a change in the global climate pattern may explain the Mayans' collapse. Yet the historical climate record of the Western Hemisphere suggests that around A.D. 950, temperatures increased and the climate changed; at precisely the same time as the Mayan collapse, far to the north, Leif Eriksson sailed through the Labrador Sea between the new settlements of his father, Eric the Red, in Greenland and North America and became the first European to set foot on what he called Vinland.

Thus began the global climate shift known as the medieval warm epoch. Although it is understood as a European phenomenon, it clearly seems to have been a shift in the global climate pattern, recorded in North America by the first Europeans there. Indeed, the climate shift was the reason they were able to go there at all. Up until around 900, the North Atlantic sea routes from Scandinavia and Iceland to the new communities in Greenland had been completely frozen over and impassable. And at the end of the warm epoch, around 1300, temperatures began to fall, and sea ice again blocked the routes. The sporadic trips to Vinland had already ceased; soon the ships could no longer travel from Greenland back to Iceland for supplies. A generation later the last settlers froze to death, and Leif Eriksson's voyage was eclipsed in history by that of a southern European, Columbus.

But what happened to the climate in Yucatán around 950? If a new climate pattern permitted the settlement of Greenland and — however briefly — North America, could it have made the Mayan civilization in Central America suddenly untenable as flora and fauna changed, as pests migrated north from the equator, as rainfall patterns were altered, and as the fierce tropical sunshine took its toll on a society that had grown up in a slightly cooler and more hospitable climate? That may be at least part of the solution to the mystery of the disappearing Mayans.

After the warming epoch, temperatures dropped again at the beginning of the fourteenth century, causing major problems in Europe and Asia. To begin with, the transition suddenly brought repeated waves of humidity sweeping from the North Atlantic through the British Isles and across vast areas of the continent. For almost ten years, rotted harvests and flooded rivers doomed the people of western Europe to a series of famines that reached their peak in the Great Famine of 1315–17. In 1315, Guillaume de Nangis reported from Rouen and Chartres that crowds of pitiful, emaciated men and women were coming to the churches in terrified processions to pray for relief from the unrelenting rains. "We saw a large number of both sexes, not only from nearby places but from places as much as five leagues away, barefooted, and many even, except the women, in a completely nude condition," he said, "with their priests coming together in procession at the Church of the Holy Martyrs." That year and the next, the European grain harvests were completely destroyed. Le Roy Ladurie reported that the summer of 1316 "was so damp there was not even enough good weather to shear the sheep." The repeated famines caused an unprecedented number of deaths; but worse was to come with the Black Death, thirty years later.

Just before the Black Death, four years of poor weather and crop failures caused widespread malnutrition and increased suscepti-

bility to disease, leading some to fear a repetition of the Great Famine. These fears stimulated grain imports from Asia Minor, among other places, which brought diseased rats first to Constantinople and then to the ports of Messina and Marseilles. From there, they and the plague they carried spread in only two years to wipe out as much as a third of the population of western Europe.

The plague itself actually originated in China, where the first reported deaths occurred in 1333. One year earlier, as a result of the same global climate changes that produced constant rains in Europe, unusually heavy rainfall in China caused the repeated Yellow River floods, which had grown steadily worse since 1327. They culminated in the largest flood of the Middle Ages in 1332, when a reported 7 million Chinese people lost their lives.

"There can be little doubt that the waters had dislocated the habitats of the wildlife as well as the human settlements, including those of the plague-carrying rodents," writes the climate historian Hubert H. Lamb. He concludes, "It is probably no coincidence that the Bubonic plague epidemic, which ultimately swept the world as the Black Death, started in 1333 in China" — the year following the great flood, in areas where decomposing human corpses had been numerous.

One of the most important and well-documented climate fluctuations is known as the Little Ice Age (1550–1850), which was associated with significant social changes all across Europe. People spent more time indoors, keeping warm around suddenly popular fireplaces, and partly as a result, new patterns of social relations evolved. The exchange of ideas about subjects like science intensified. Romantic ideals took on a new significance in the arts, as did the concept of the individual in politics. Outdoors, however, the new climate realities were harsh for some in northern Europe.

Imagine the shock in Aberdeen, Scotland, in 1690, when an Eskimo in his kayak appeared in the River Don. The migration of Europeans toward Greenland had long since come to a frozen halt, but the Eskimos' favored habitat was now extending south as far as the Orkney Islands and northern Scotland.

The Scots, confronted with the failure of their cod fisheries and their crops, experienced repeated famines and began to leave their homeland. By 1691, 100,000 Scots, a tenth of the population, had

settled in the part of Ireland closest to Scotland, Ulster (now known as Northern Ireland), displacing and evicting the native Irish and setting in motion the enormous problems and seemingly insoluble violence that continue to this day.

In the years following the Scottish migration, Ireland as a whole continued to grow in population. Historians generally agree that Ireland became a social and political mess; England's dominance led to a number of foolish decisions, of which the decision by King James VI to facilitate the Scottish migration was only the first. Archaic rules of land ownership helped to create a culture of poverty, which in turn encouraged early marriage and further population growth. Between 1779 and 1841 the population increased by 172 percent, making Ireland, by Disraeli's estimate, the most densely populated area of Europe. The fateful decision to rely almost exclusively on a single food crop — potatoes — for subsistence set the stage for the horrible tragedy known as the Great Potato Famine.

As the Little Ice Age drew to a close, average temperatures rose slightly, enough to create the wet and warm climate conditions conducive to potato blight. Modern laboratory studies show that the particular blight that struck Ireland, *Phytophthora infestans*, requires a period of at least twelve hours with the relative humidity at 90 percent or more with temperatures at 10 degrees Centigrade or higher and free water on the potato leaves for at least another four hours. The possibility of such conditions coming together were much lower during the Little Ice Age, when Ireland began to depend on the potato; by the mid-1840s the odds had improved with the new warming trend.

The blight seems to have originated in a new strain of potatoes from Peru; it first appeared in the northeastern United States in 1843 and in Flanders the following year. By the summer of 1845 the spores had spread to Ireland. That winter was one of the warmest the Irish could remember; the spring was also warm, and in June temperatures soared to an average three to four degrees warmer than the hundred-year average. That summer as a whole was the second warmest of the nineteenth century. On top of that, there were sixty-four days of rain in July, August, and September, twenty-four in August alone.

The blight struck with a terrible vengeance at the one crop by

which Ireland lived or died. More than a million people died in Ireland during the next few years of starvation and diseases related to malnutrition. The horrific reports of the survivors give us some sense of what the famine meant in human terms. In December 1846, the father of two very young children in County Cork died of starvation (as their mother had previously). According to the inquest, "His death became known only when the two children toddled into the village of Schull. They were crying of hunger and complaining that their father would not speak to them for four days; they told how he was 'as cold as a flag.' The other bodies on which an inquest was held were those of a mother and child who had both died of starvation. The remains had been gnawed by rats."

A contemporary newspaper report recorded this typical eyewitness account: "In a cabbage garden I saw the bodies of Kate Barry and her two children very lightly covered with earth, the hands and legs of her large body entirely exposed, the flesh completely eaten off by the dogs, the skin and hair of the head lying within a couple of yards of the skull, which, when I first threw my eyes on it, I thought to be part of a horse's tail. . . . I need make no comment on this, but ask, *are we living in a portion of the United Kingdom?*"

The practice of growing a single crop over vast areas instead of a variety of plants is known as monoculture. The problem is the risk of vulnerability to a plant disease or a resistant pest that suddenly wipes out the whole crop. This vulnerability is even greater when a single strain of a single crop is used. The Irish had come to rely on a single strain of potatoes as virtually their sole source of food, a strain that maximized yields in the climate conditions that had prevailed for the previous 300 years. The story of the potato famine is a lesson in how artificial modifications to our relationship with nature, like monoculture, that fail to take into account the vagaries of natural climate change can increase the vulnerability of a society attempting to feed its people. It also shows how a rapid warming can cause catastrophe.

Historically, climate tragedies like the one that caused the potato famine have led to massive migrations toward wealthier countries,

especially the United States. Three decades earlier, the great subsistence crisis of 1816–17 had also stimulated a flood of migration, not only from Europe to the United States but — because the effects of the climate change were felt well beyond Europe — also within the United States. For example, historical accounts of the westward migration from Maine indicate that after "the uncommonly cold and unpropitious" springs of 1816 and 1817, a terrible fear of famine lent "a fresh impulse to the enchanting spirit of emigration. Hundreds who had homes, sold them for small considerations, and lost no time in hastening away into a far country." The connection between the migration from Maine and the unusual climate patterns caused in 1816–17 by the Tambora volcano tends to be bolstered by the statistics: they show that once the unusual climate patterns ended (when the dust of the volcano fell back out of the atmosphere), in 1818, Maine resumed its steady population growth. An identical pattern was documented in New Hampshire, Vermont, Connecticut, and the Carolinas. One eyewitness wrote that "a sort of stampede took place . . . during the summer of 1817."

Perhaps the largest forced migration in American history was the mass departure from Kansas, Oklahoma, Texas, parts of New Mexico, Colorado, Nebraska and other Plains states during the period of the early 1930s referred to as the Dust Bowl years. Like the Great Potato Famine, the Dust Bowl resulted from unwise land use, which heightened the vulnerability of the land and its people to unexpected climate changes. During the 1920s, there was a revolution in agriculture throughout the High Plains states. Mechanization led to the development of the tractor, the combine, the one-way plow, and the truck. These, in turn, led to the "great plow-up" of the late 1920s. Agricultural experts mistakenly believed that the repeated plowing of land until it was smooth and pulverized made it better able to absorb and hold rainwater. Agronomic research, focusing on different ways to increase water absorption, completely overlooked the problem of wind erosion, which became a far more serious threat because of these very changes in agricultural methods.

For a few years there were record crops, and the early warning signs of wind erosion were ignored. Even when acreage was left

fallow, the farmers continued to plow it as a way of discouraging weeds and, again, encouraging the absorption of moisture, to assure a good start when the wheat was planted.

The fall of 1930 and the spring and summer of 1931 brought heavy rains and hardship but a record harvest nonetheless. After a dry winter, in March 1932 strong winds began to blow through and take some of the topsoil with them. The spring rains were scattered and deficient, and then, in early summer, flooding from hard rains eroded the soil, punctuating a drought that had made the summer unusually dry overall. The fall was quite dry, and by the onset of winter many fields had been abandoned.

The big dust storms began in January 1933 and continued off and on for more than four years, devastating the crops, dispiriting the people, and creating nightmarish conditions, leading many to pick up stakes for California or back east. In 1934, Secretary of the Interior Harold Ickes advised the people of the Oklahoma panhandle to simply leave their homes. Only 15 percent of the acreage between Texas and Oklahoma would be harvested that year.

Those who stayed, actually the majority, also suffered. In Colorado, the editor of the *Morton County Farmer* wrote in the spring of 1935,

> We can see nothing out our windows but dirt, every time our teeth (or the dentist's, or maybe you have your store teeth paid for) come together, you feel dirt and taste it; haven't heard a thing for hours, my ears are full, can't smell, my nose is full, can't walk, my shoes are full but not of feet . . . we are and have been having a dirt storm. It hasn't been real life for two days. Everything is covered with a little of Old Mexico or Texas or Colorado or what have you . . . The earth looks hard and barren — everybody has a dirty face, even your creditors hardly know you. But there is no way out — not even out of our front door. We live in a dugout and slide down the steps now. Diving out the window is fun after you get used to it.

Emergency hospitals were set up to treat the many cases of "dust pneumonia," a collection of bronchial and other respiratory diseases caused and made worse by the constant inhalation of dust. The dust and dirt from the continuing storms blew all the way to the Atlantic Ocean. Not until 1937 did conditions finally stabilize.

Of course, the history of climate change is also the history of human adaptation to climate change. During the subsistence crisis of 1816–17, for example, the bureaucratic, administrative tendencies of the modern state were given great impetus. In virtually every European country, central governments organized and distributed the scarce supplies of food and imported new stocks from Odessa, Constantinople, Alexandria, and America. For the first time, large-scale public works projects were organized chiefly to provide employment in the hope of staving off the popular disturbances and food riots that accompanied the subsistence crisis. In the 1930s, the Dust Bowl was among the many disruptive social and economic problems that led to an even more complex version of the administrative state, Franklin Roosevelt's New Deal.

All of these changes in climate patterns took place during temperature variations of only 1 to 2 degrees Centigrade. Yet today, at the close of the twentieth century, we are in the process of altering global temperatures by up to three to four times that amount and causing changes in climate patterns that are likely to have enormous impacts on global civilization. Among the most dramatic effects, if the historical record is any guide, will be massive migrations of people from areas where civilization is disrupted to other areas where they hope to find the means for survival and a better way of life — but with unpredictable consequences for those areas.

About 10 million residents of Bangladesh will lose their homes and means of sustenance because of the rising sea level, due to global warming, in the next few decades. Where will they go? Whom will they displace? What political conflicts will result? That is only one example. According to some predictions, not long after Bangladesh feels the impact, up to 60 percent of the present population of Florida may have to be relocated. Where will they go?

Florida has already borne the brunt of one of the largest ecologically induced migrations of this century: some 1 million people emigrated from Haiti to the United States in the last decade — not only because of political oppression but also because the worst deforestation and soil erosion in the world made subsistence farming impossible for them. Although some of the Haitians have been

absorbed, most have not, and all have suffered greatly, enduring perilous journeys and uncertain futures.

Sir Crispin Tickell, a leading British diplomat and environmentalist, noted in a speech to the Royal Society in London in 1989 that "a heavy concentration of people is at present in low-lying coastal areas along the world's great river systems. Nearly one third of humanity lives within sixty kilometers of a coastline. A rise in mean sea level of only twenty-five centimeters would have substantial effects . . . a problem of an order of magnitude which no one has ever had to face . . . in virtually all countries the growing numbers of refugees would cast a dark and lengthening shadow."

In the developed world, we now have the ability to insulate most people from the kind of suffering, disease, famine, and forced migration that, in the ancient world, often accompanied fluctuations in the global climate equilibrium and the attendant disruptions of the weather patterns upon which those fragile civilizations depended. But we insulate ourselves by burning even more fossil fuels and creating still more CO_2. And as we continue to expand into every conceivable environmental niche, the fragility of our own civilization becomes more apparent. Moreover, as the world population surges, our resilience in the face of climate variability is diminishing. In any event, the climate changes that we are now bringing about by modifying the global atmosphere are likely to dwarf completely the ones that caused the great subsistence crisis of 1816–19, for example, or those that set the stage for the Black Death.

In the course of a single generation, we are in danger of changing the makeup of the global atmosphere far more dramatically than did any volcano in history, and the effects may persist for centuries to come. The global temperature changes for which we are responsible are likely to be five times larger than the fluctuations that produced the Little Ice Age, for example, or the global climate change that led to the Great Famine of 1315–17.

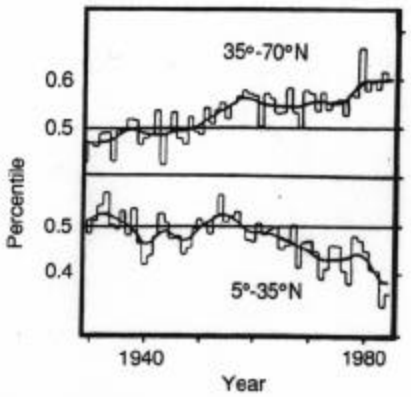
As increased ultraviolet radiation weakens the human immune system, especially in the tropics, and as explosive population growth and urbanization continue to disrupt traditional cultural patterns, hundreds of millions of people may well become even more susceptible to the spread of diseases when populations of

pests, germs, and viruses migrate with the changing climate patterns.

Our increasingly aggressive encroachment into the natural world and the resulting damage to the ecological systems of the earth have weakened the resilience of the global environment itself and threatened its very ability to maintain its equilibrium.

And how will the world respond? During the Irish potato famine, a combination of blind devotion to laissez-faire economics, cold indifference to suffering, anti-Irish racism, and anti-Catholic bigotry contributed to the United Kingdom's tragic failure to respond humanely. Given the advances of civilization since then, it is difficult to imagine that such a horror would be tolerated today. However, the number of children dying of starvation on an average day in our modern world is more than forty times greater than the number who starved on an average day at the height of the famine. The scenes going on right before our eyes today are just as terrible as the accounts from 1846. A combination of blind devotion to laissez-faire responses, political ineptitude in the countries affected, the paralysis that even a little bit of racism can promote, and the willful blindness of "denial" are promoting the continuation of our own great famine right now. It would not be at all surprising to hear an eyewitness in Ethiopia or the Sudan echo the observer of the famine victims and cry out, "Are we living in a portion of the same planet that has the United States and Europe and Japan?"

Actually, new climate analyses now show conclusively that the dramatic increase of famine in those areas of Africa that include Ethiopia, the Sudan, and Somalia coincides with a dramatic shift in rainfall patterns. "There was little trend in precipitation until the 1950s when, after a relatively wet episode, precipitation [in Northern Africa and the Middle East] declined drastically," a decline that has continued and accelerated for the last forty years, accompanied by concurrent "significant increases in [European] precipitation." So reported a team of researchers in *Science* in 1987, after an extensive array of climate measurements covering a century and a half identified large shifts in rainfall patterns over recent decades. Their study found that while rainfall steadily *decreased* in the Sahel portion of Africa and the Middle East, it steadily *increased* proportionally in Europe.



The bottom line here shows the steady decline of rainfall in the latitudes of Africa where repeated droughts and famine have killed tens of millions of people in recent years. The top line shows a mirroring increase in precipitation over the same period in the latitudes that include Europe.

These researchers are worried that this forty-year trend, which has been one of many factors in producing repeated and persistent famines, is an early consequence of global warming; if so, it may indicate even more disruptive changes in climate patterns as the warming continues. Another climate expert, Hubert Lamb, writing about the recent forty-year trend in the Sahel and the mass famines and immigrations that have accompanied it, said, "Some complete national territories may, in the long run, become more or less uninhabitable if the development continues and goes further." However, in spite of the circumstantial evidence, climate researchers are reluctant to link global warming definitively to these catastrophic changes because the phenomena involved are so complex.

It is possible, however, to draw some inescapable conclusions from what they have observed. This much is certain: fragile societies in the midst of a modern, affluent global civilization are

undergoing enormous suffering partly as a consequence of a shift in climate patterns, whatever the cause of the shift may be. Meanwhile, the rest of the world has been unable to provide more than stopgap solutions for their suffering.

Moreover, even after highly publicized warnings from virtually the entire global scientific community that the current pattern of our civilization is creating dramatic changes in global climate patterns, likely to be many times larger than any experienced in the last 10,000 years, we are doing virtually nothing to address the principal causes of this catastrophe in the making. We know from the history of climate changes that they can cause unprecedented social and political upheavals, especially in fragile, densely populated societies. Ironically, we are ignoring the lessons of the Irish famine and shifting global agricultural patterns toward an unprecedented and increasing dependence on monoculture.

The lessons of the Dust Bowl are also being ignored. Sweeping changes in patterns of land use that turn out to be disastrously inappropriate are far more common today than in the decade before the Dust Bowl. The massive clearing of tropical rain forests is, of course, an ecological catastrophe of the first magnitude, beside which the Dust Bowl pales in comparison — not least because the earth could at least recover from the latter in a few generations, whereas the damage from the former could last for tens of millions of years. The sudden irrigation of the vast desert areas surrounding the Aral Sea in Soviet Central Asia represents another tragic mistake from which recovery may be difficult, if indeed it is possible at all.

Sometimes the damage from inappropriate land use is more subtle. In California, for example, using massive quantities of water from the northern part of the state to irrigate rice fields in southern areas reclaimed from the desert seemed like a good idea — until a new drought cycle began to hit the West in the late 1980s. During the last drought that approached the severity of the recent one (in the 1930s), California had 18 million people and proved resilient enough to endure the climate extreme. In 1991, with 32 million people, California may have been just as resilient, but fewer than 80,000 farmers use 85 percent of the state's water. As a result, the effects of the drought have been extremely disruptive.

In this period of extraordinary population growth, we have grown accustomed to the idea that the pressure of population on the environment is something new. But it is actually a recurrent theme in the history of environmental change. For example, climate historians have speculated that a similar pattern of expansion beyond the environment's carrying capacity may provide an explanation for the mysterious disappearance around the year 1280 of southwestern Colorado's Anasazi civilization, which occupied the spectacular cliff dwellings of Mesa Verde. Fairly reliable evidence indicates that its disappearance corresponded with a drought which, while severe, was not dissimilar from earlier droughts that the cliff dwellers successfully endured. According to the archaeological record, however, there was one crucial difference this time around: the Anasazi population had grown significantly larger just before its disappearance.

The lesson from this experience is almost unbearably obvious. Our global civilization, which after the many thousands of generations up to the end of World War II had reached a population of fewer than 2.5 billion people, may, by quadrupling in the space of a single lifetime, dramatically increase our vulnerability to the extreme climate changes that we ourselves are now setting in motion.

The signs of increased vulnerability are already evident, not only in the Sahel and the Amazon and the Aral Sea but in California and Florida and the High Plains states, which are now using up their underwater aquifers just as surely as Kansans once pulverized their topsoil until it blew away. The pressure of the population at the foothills of the Himalayas has led in the last few decades to such extensive deforestation that the rains now rush wildly down the slopes, across Bangladesh and eastern India, carrying an enormous tonnage of topsoil to silt up the Ganges River system and worsen the flooding that results. The Bay of Bengal is almost perpetually brown with the soil that ought to be growing crops. In my own state of Tennessee, the same phenomenon is occurring in a different form: new subdivisions strip the hillsides of the vegetation that used to soak up the rain; the creeks and rivers silt up and in some counties what used to be called a hundred-year flood now comes every few years.

It is now clear that the relationship between humankind and climate change has been reversed: where civilization once feared Nature's whim, the earth must now suffer ours — though we may yet relearn a healthy fear of disturbing nature's balance.

It is worth noting as well that the relationship between humankind and evolution has also begun to reverse. The current "era" in which we are living is described by geologists as the cenozoic era. Beginning 65 million years ago with the disappearance of the dinosaurs, the cenozoic era has been characterized by the flourishing of a larger number of more varied life forms than during any previous era in the earth's 4.6-billion-year history. Now, as the theologian Thomas Berry notes, human civilization, because it is destroying as many as half of all the living species on earth during the lifetimes of persons now living, is in effect bringing about the end of the cenozoic era — in our lifetimes.

What comes next? The "year without a summer" in 1816 produced massive famines and helped stimulate the emergence of the administrative state. What will global warming produce — a new worldwide bureaucracy to manage the unimaginable problems caused by massive social and political upheavals, mass migrations, and the continuing damage to the global environment by civilization itself? Is that what we want? Wouldn't it be better to prevent the chaos instead of scrambling to cope with it after it occurs?

The story of humankind and our relationship to the earth may be seen as a continuing adventure or a tragedy shrouded in mystery. The choice is ours. The "year without a summer" teaches us how vulnerable civilization is to small global climate changes. In the lifetimes of people now living, we may experience a "year without a winter." But, unlike the transient climate changes associated with volcanic emissions, we are carelessly initiating climate changes that could well last for hundreds or even thousands of years. The ancient civilizations that disappeared during significant natural climate changes in the past could tell us a great deal that we seem not to want to hear. What if our children, because of our actions, face not just a year without a winter but a decade without a winter? Will that be our most significant legacy? The answer may well depend on whether we can learn from the ancient cultures that disappeared.

If we do not, if we instead persist in our willful ignorance of the powerful changes we are setting in motion, we may ultimately leave little more than a mystery to puzzle some new human community in the distant future, trying to understand what happened to the ancient lost civilization that made such grand structures of concrete and steel and plastic so long ago.

4

Buddha's Breath

The magnitude of the changes we are imposing on the world's climate pattern is made obvious from the perspective of history, but in any given year our attention is likely to focus on the swirl of contemporary events — and specific problems with pollution, particularly of the air. No sooner had the political dust of Eastern Europe's revolution against communism settled in 1989 than the world gasped in horror at the unbelievable levels of pollution — especially air pollution — throughout the communist world. We learned, for example, that in some areas of Poland, children are regularly taken underground into deep mines to gain some respite from the buildup of gases and pollution of all sorts in the air. One can almost imagine their teachers emerging tentatively from the mine, carrying canaries to warn the children when it's no longer safe for them to stay above the ground.

One visitor to the Romanian "black town" of Copsa Mica noted that "the trees and grass are so stained by soot that they look as if they had been soaked in ink." A local doctor reported that even horses can stay only for two years in the town; "then they have to be taken away, or else they will die."

In the northern reaches of Czechoslovakia, the air is so badly polluted that the government actually pays a bonus to anyone who will live there for more than ten years; those who take it call it burial money. To the east, in the Ukraine, that one republic puts eight times as many particulates into the air each year as does the entire United States of America.

Throughout the developing world, similar nightmares are found