

## 2. Historical Evidence on Climate and Human Well-Being

*Climate extremes would trigger meteorological chaos—raging hurricanes such as we have never seen, capable of killing millions of people; uncommonly long, record-breaking heat waves; and profound drought that could drive Africa and the entire Indian subcontinent over the edge into mass starvation. . . . Even if we could stop all greenhouse gas emissions today, we would still be committed to a temperature increase worldwide of two to four degrees Fahrenheit by the middle of the twenty-first century. It would be warmer than it has been for the past two million years. Unchecked it would match nuclear war in its potential for devastation (Mitchell 1991, 70-71).*

—former Senate Majority Leader George J. Mitchell

Senator Mitchell's forecast and his history are both wrong. Warmer periods bring benign rather than more violent weather. Milder temperatures will induce more evaporation from oceans and thus more rainfall—where it will fall we cannot be sure, but the earth as a whole should receive greater precipitation. Meteorologists now believe that any rise in sea levels over the next century will be at most a few feet, not 20 (NRC 1991, 24). In addition, Mitchell flunks history: around 6,000 years ago the earth sustained temperatures that were probably more than 4° Fahrenheit hotter than those of the 20th century, yet mankind flourished. The Sahara desert bloomed with plants, and water-loving animals, such as hippopotamuses, wallowed in rivers and lakes. Dense forests carpeted Europe from the Alps to Scandinavia. The Midwest of the United States was somewhat drier than it is today, similar to contemporary western Kansas or eastern Colorado; but Canada enjoyed a warmer climate and more rainfall.

What is well known is that climate changes. The world has shifted from periods that were considerably warmer—during the Mesozoic era when the dinosaurs thrived, the earth appears to have been

about 18°F warmer than now—to spells that were substantially colder, such as the Ice Ages when huge glaciers submerged much of the Northern Hemisphere (Levenson 1989, 25). One paleoclimatologist estimated that, during the Precambrian period, the polar regions were about 36°F colder than they are in the contemporary world (Huggett 1991, 74). During the last interglacial era, about 130,000 years ago or about when modern man was first moving out of Africa, the average temperature in Europe was at least 2° to 5°F warmer than at present (Crowley and North 1991, 117). Hippopotamuses, lions, rhinoceroses, and elephants roamed the English countryside. Areas watered today by the monsoons in Africa and east Asia enjoyed even more rainfall then. Indeed during the last 12,000 years (that is, since the end of the last glacial period), the globe has alternated between times substantially warmer and epochs that were noticeably cooler than today's climate.

An examination of the record of the last 12 millennia reveals that mankind prospered during warm periods and suffered during cold ones. Transitions from warm to cold periods or vice versa were difficult for people who lived in climates that were adversely affected yet benefited those who inhabited regions in which the weather improved. On average, however, humans gained during the centuries in which the earth enjoyed higher temperatures. In writing about the effect of climate change on human development, then Senator and now Vice President Al Gore admits:

The archaeological and anthropological records indicate that each time the ice retreated [during the Ice Ages], the primitive peoples of the Eurasian landmass grew more populous and their culture more advanced. . . . Then, 40,000 years ago, the so-called cultural explosion of tools and jewelry may have coincided with an unusually warm millennium in Europe (Gore 1992, 62-63).

### **Historical Evidence**

History provides the best evidence for the effect of climate change on humans, plants, and animals; but a few researchers have challenged its relevance. David Rind (1993, 39–49), a climate modeler and NASA scientist, has questioned the applicability of past warming episodes to the modern issue of climatic alteration caused by increased CO<sub>2</sub> concentrations. He attributes the origin of past periods of warmth and cold to shifts over time in the orbital position of the

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earth that impose more or less energy on the poles, as contrasted with a general worldwide warming that might result from the addition of man-made greenhouse gases. He also argues that the swiftness in warming that would occur following increased levels of CO<sub>2</sub> is unprecedented in history. On the latter point, he ignores other research, such as that by a German academic, Burkhard Frenzel, who writes (1993, 7), "During the Holocene [since the last Ice Age], very rapid changes of climate occurred. According to dendroclimatology [tree ring analysis applied to climatology], they often lasted about 20 to 30 years, or [were] even as brief as 2 to 3 years." Other climate historians have found that a rapid cooling in the late glacial period—about 11,000 years ago—took about 100 to 150 years to complete and realized about 5°F variation in temperature within 100 years, more than is being forecast for the next century (Flohn 1983, 404).

Although changes in the earth's orbital position may easily have played a role in warming the earth after the last Ice Age, the effect was worldwide rather than concentrated in northern latitudes. Ice retreated in the Southern as well as in the Northern Hemisphere. Moreover, in the subsequent warming, from around 7,000 to 4,000 years ago, the climate around the world appears to have improved. The evidence for warming in the Southern Hemisphere is weaker but, even if higher temperatures had been localized in one hemisphere or one continent, the effect on human beings would still tell us about the benefits or costs of climatic change. Dr. Rind argues that greenhouse warming would raise winter as well as summer temperatures while past warmings, driven by orbital mechanics, have raised summer temperatures alone. Even though his models suggest that these past warmings should have boosted temperatures solely in June, July, and August, the evidence, albeit a little tenuous for the 3,000-year period of Climatic Optimum, supports warmer winters. For the Little Climate Optimum that coincided with the High Middle Ages, researchers have found strong support for mild winters.

Moreover, at a recent conference the Russians have put forward the hypothesis that past climate changes support the proposition that the cause of the warming or cooling is irrelevant; the pattern has been the same (Broccoli 1994, 282). This conclusion, disputed by some, is based on a large number of past shifts in average weather

conditions dating back millions of years. The Russians contend that the climate models overstate the amount of temperature change at the equator and understate it at the poles.

### **Measurement of Human Well-Being**

Since statistics on the human condition are unavailable except for the most recent centuries, I shall use indirect methods to demonstrate the influence of climate on man's well-being. Growth of the population, major construction projects, and a significant expansion in arts and culture all indicate that a society is prosperous. If the population is expanding, food must be plentiful, disease cannot be overwhelming, and living standards must be satisfactory. In addition, if building, art, science, and literature are vigorous, the civilization must be producing enough goods and services to provide a surplus available for such activities. Renaissance Florence was rich; Shakespeare flourished in prosperous London; wealthy Vienna provided a welcome venue for Haydn, Schubert, Mozart, and Beethoven.

Clearly climate is far from the only influence on man's well-being. Governments that extort too much from their people impoverish their countries. A free and open economy stimulates growth and prosperity. War and diseases can be catastrophic. At the same time, a change in climate frequently has been a cause of war or has aided the spread of disease. A shift to more arid conditions, for example, impelled the Mongols to desert their traditional lands to invade richer areas. A cold, wet climate can also confine people to close quarters; confinement can abet contagion. Moreover, a shift toward a poorer climate can lead to hunger and famine, which establish conditions in which disease becomes virulent.

Throughout history climatic changes probably forced technological innovations and adaptations. The shift from warm periods into Ice Ages and back again likely accelerated the evolution of modern man. Each shift would have left small groups of hominids isolated and subject to pressures to adapt to new weather conditions. Those shifts, especially to the more adverse conditions created by the spread of extreme cold, put strong selection pressure on the human forebears that ultimately led to modern man. Even after *Homo sapiens* started spreading across the earth, climate shifts fostered new technologies to deal with changed circumstances.

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With the growth in wealth and resources, the influence of climate on human activities has declined. Primitive man and hunter-gatherer tribes were at the mercy of the weather, as are societies that are still almost totally bound to the soil. A series of bad years can be devastating. If, as was the usual case until very recently, transportation is costly and slow, even a regional drought or an excess of rain in one area can lead to disaster, although crops may be plentiful a short distance away. Thus variation in the weather for early man had a more profound influence on life and death than do fluctuations in temperature or rainfall in modern times when economies are more developed. Since the time of the Industrial Revolution, climate has basically been confined to a minor role in human activity.

#### **Climate History**

From its beginnings, the earth has experienced periods significantly warmer than the modern world—some epochs have been hotter than the most extreme predictions of global warming—and times much colder than today. Today's cool temperatures are well below average for the globe in its more than 4 billion year history (Giles 1990, 23). During one of the warmest such eras dinosaurs roamed the earth and a rich ecological world flourished.

As mentioned, studies of climate history show that sharp changes in temperatures over brief periods of time have occurred frequently without setting in motion any disastrous feedback systems that would lead either to runaway heating that would cook the earth or freezing that would eliminate all life. In addition, carbon dioxide levels have varied greatly. Ice core data exhibit fluctuating levels of CO<sub>2</sub> that do not correspond to temperature changes (Frenzel 1993, 8). Most past periods display a positive relationship between CO<sub>2</sub> and temperature, however, with a relationship roughly corresponding to that of the Global Climate Models (Crowley 1993, 23). During interglacial periods high latitudes enjoyed temperatures that were about 5° to 11°F warmer than today (Frenzel 1993, 10). Middle latitudes experienced temperatures only about 4° to 5°F warmer. The warmer periods brought more moisture to the Northern Hemisphere, with the exception of central North America during the Holocene. At the time of the medieval warm period, temperatures in Europe, except for the area around the Caspian Sea basin, were

1° to 3°F higher and rainfall was more plentiful than today (Frenzel 1993, 11).

The historical evidence is consistent with only some of the forecasts of the computer climate models. Most climate estimates indicate that a doubling of CO<sub>2</sub> would generate greater rainfall in middle latitudes, and history shows that warm climates do produce more wet weather (Crowley 1993, 21). The historical record shows that land temperatures should increase more than water, thus strengthening monsoons. The models also predict that sea-surface temperatures in the tropics would be higher with increased CO<sub>2</sub>, but evidence from the past evinces no such relationship (Crowley 1993, 25).

Carbon dioxide concentrations may have been up to 16 times higher about 60 million years ago without producing runaway greenhouse effects (Rind 1993, 41). Other periods experienced two to four times current levels of CO<sub>2</sub> with some warming. Scientists have been unable to determine whether the warming preceded or followed the rises in carbon dioxide. For virtually all of the period from around 125 million to about 75,000 years ago, CO<sub>2</sub> levels were markedly higher than now.

The prevailing view among climatologists is that the Climatic Optimum—9,000 to 4,000 years ago—resulted from orbital mechanics that increased summer radiation in the Northern Hemisphere, although winters received less heat than they do in the modern world (Webb et al. 1993, 517). Over several millennia, the warmer summers melted the northern glaciers. Warmer lands in the interior of northern continents and cooler oceans drove the monsoons farther north to bring greater rainfall to the Sahara, Arabia, and southern and eastern Asia (Webb et al. 1993, 521). North of the monsoon area, the climate was drier than today. Anatolia, Northwestern Africa, parts of China, and northern Japan experienced less rainfall (Webb et al. 1993, 523). By 4000 B.C., however, a slackening of the trade winds had produced warmer Atlantic ocean water off northwestern Africa; as a consequence, the Middle East, including Greece and modern Turkey, was enjoying more reliable rain.

If orbital variations produced the Climatic Optimum, the Southern Hemisphere should have been cooler. Between 10,000 B.C. and 7,000 B.C., however, winter temperatures (June, July, August) below the equator warmed to levels higher than today while summer temperatures (December, January, February) were cooler than in the modern

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world (Webb et al. 1993, 525). Rainfall over South America, Australia, and New Zealand was apparently lighter than at present. Although the Southern Hemisphere moved out of the Ice Age in tandem with the Northern Hemisphere, its climate since then has not tracked as closely weather patterns north of the equator (Morley and Dworetzky 1993, 133–34). Data based on vegetation suggest that annual temperatures in New Zealand were coldest between 20,000 and 15,000 years ago, warmed subsequently, and peaked between 10,000 and 8,000 years before the present—somewhat earlier than they did in the Northern Hemisphere (McGlone et al. 1993, 311). Temperatures appear to have been falling over the last 7,500 years. By 1500 B.C., the climate was quite similar to today's (McGlone et al. 1993, 313).

Whether the whole globe warmed or not during the period 7,000 to 4,000 years ago is really irrelevant to the question of how hotter temperatures affect humans. If the Northern Hemisphere warmed, and there is good evidence that it did, then considering how people survived in that portion of the globe provides information about how higher global temperatures would influence mankind.

Modern humans apparently evolved into the current genotype between 40,000 and 200,000 years ago, probably in Africa during an Ice Age (Vigilant et al. 1991, 1503–07). Around 150,000 years ago the extent of ice coverage reached a maximum, followed around 130,000 years before the present (B.P.) by a rapid deglaciation (Crowley and North 1991, 116). The warm interglacial era, during which temperatures may have exceeded those forecast under a doubling of greenhouse gases, lasted about 15,000 years until the onset of renewed glaciation at 115,000 B.P. Over the next 100,000 years the glaciers fluctuated with the climate, but at no time did the average temperature equal the level of the previous interglacial epoch or reach the warmth of the last 10,000 years (Crowley and North 1991, 20).

In the thousands of years of the last Ice Age preceding the current warm epoch, man existed as a hunter-gatherer in a world that looked quite different from today's. Herds of large animals, such as bison, mammoths, and elk, roamed a largely treeless savanna in Europe. Those beasts made easy prey for human hunters who enjoyed as a consequence a rich diet of wild animal meat plus, in season, local fruits and vegetables. It was during the Ice Age that the level of the

oceans fell sufficiently to allow Asian peoples to migrate across what is now the Bering Strait but was then dry land. Most archaeologists date the first arrival of humans in the Americas from around 15,000 years ago, although some have claimed evidence for an earlier arrival. No doubt the lower sea levels during the Ice Age also facilitated the arrival of the aborigines in Australia some 35,000 years ago.

Climatologists consider that the last Ice Age ended about 12,000 to 10,000 years ago when the glaciers covering much of North America, Scandinavia, and northern Asia began to retreat to approximately their current positions. In North America the glacial covering lasted longer than in Eurasia because of topographic features that delayed the warming. Indeed, throughout history warming and cooling in different regions of the world have not been exactly correlated because of the influence of oceans, mountains, prevailing winds, and numerous other factors. Nevertheless, across the Northern Hemisphere large temperature shifts have occurred roughly together—perhaps in some areas they have lagged other zones by a century or more. The correspondence between warming and cooling in the Northern Hemisphere and that in the Southern is less well known and, as noted, may be less well correlated because of the predominance of water south of the equator and the existence of Antarctica.

Human progress, a few improvements in hunting tools and some cave art, was incredibly slow during the Ice Age, a period whose length dwarfs the centuries since. Over the last 12 millennia of interglacial warmth, however, modern people have advanced rapidly. The growth in technology and living standards required a climate that was more hospitable than existed throughout that frozen period.

During the last Ice Age humans survived through hunting and gathering. Initially archaeologists believed that those bands, which typically consisted of 15 to 40 people, eked out a precarious existence (Ammerman and Cavalli-Sforza 1984, 4). On the basis of studies of the few bands of hunter-gatherers that survived into the 20th century, however, many modern archaeologists believe that they normally found food plentiful in their forays and would rarely have been hungry. Modern primitive people, however, may not have been typical of earlier groups. The ones that did face food pressures would have adopted farming while those that found ample supplies

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in their environment would have been less concerned with new ways of acquiring sustenance (Boserup 1981, 39–40). Food pressures could have arisen either from a change in climate that made previous ways of life untenable or an expansion of population in the region that began to overwhelm the natural supply.

As the earth warmed with the waning of the Ice Age, the sea level rose as much as 300 feet; hunters in Europe roamed through modern Norway; agriculture developed in the Middle East. For about 3,000 to 4,000 years the globe enjoyed what historians of climate call the Climatic Optimum period—a time when average world temperatures, at least in the Northern Hemisphere, were significantly hotter than today. At its height, between 4000 and 2000 B.C., the world flourished under temperatures 4° to 5°F higher than have been normal in this century (Lamb 1968, 6). During the relatively short period since the end of glaciation, the climate has experienced what have been described (Wendland and Bryson 1974) as periods of stability separated by “abrupt transition.” H. H. Lamb (1968, 12), a leading climate historian, calculates that at its coldest, during the Mini Ice Age (roughly from 1300 to 1800 A.D.), the temperature in central England for January was about 4.5°F colder than it is today. He also concludes that in the central and northern latitudes of Europe during the warmest periods, rainfall may have been 10 to 15 percent greater than now and during the coldest periods of the Mini Ice Age, 5 to 15 percent less (Lamb 1988, 30). On the other hand, cooler periods usually suffered from more swampy conditions because of diminished evaporation.

If modern humans originated more than 100,000 years ago, why did they not develop agriculture for 90 percent of that period? Even if *Homo sapiens* originated only 40,000 years ago, people waited 30,000 years to grow their first crops—an innovation that yielded a more reliable and ample food supply. Farming developed first in the Middle East, right after the end of the last Ice Age—a coincidence? The evidence suggests that, from 11,000 to 9,000 years ago, the climate became warmer and wetter in the Middle East, shifting the ecology from steppe to open woodland (Ammerman and Cavalli-Sforza 1984, 28). This led to the domestication of plants and animals, probably because the warmer, wetter weather made farming possible. From its origins around 8000 B.C., agriculture spread northward, appearing in Greece about 6000 B.C., Hungary 5000 B.C., France 4500

B.C., and Poland 4250 B.C. (Ammerman and Cavalli-Sforza 1984, 41). Is it chance that this northward spread followed a gradual warming of the climate that made agriculture more feasible at higher latitudes?

As anthropologist Mark Cohen (1977, 1) writes, "If, as the archaeological record indicates, hunting and gathering was such a successful mode of adaptation over such a long period of time, and if most human populations are as conservative as anthropologists have observed them to be, we are faced with answering the question why this form of adaptation was ever abandoned." His estimates of the efficiency of the hunting and gathering lifestyle indicate that it was more efficient than farming—at least for large game. He reports that when large animals are available, hunting brings 10,000 to 15,000 calories per hour of hunting. However, if large animals are unavailable—because the environment is poor or because they have all been killed—hunting small game will return only a few hundred to 1,500 calories per hour devoted to that effort. Collecting and processing small seeds from such plants as wild wheat may produce only 700 to 1,300 calories for each hour. Shellfish collection can produce 1,000 to 2,000 calories per hour of work. On the other hand, subsistence farming produces 3,000 to 5,000 calories per hour devoted to agriculture (Cohen 1989, 56). This connotes that hunting large animals, when and if they are available, is the most economical method of subsistence; if the beasts are exterminated or if the humans move to areas without such species, domestication of plants and animals can produce more food for the effort than any other strategy.

Moreover, hunter-gatherers can survive only if the density of their population is low. Too many mouths would strain the environment and preclude survival. Once humans developed farming that could support larger families and a denser population, however, the number of people did explode. Primitive tribes, dependent on hunting, scavenging, and collecting edibles to survive, had to hold their populations below what they might individually have preferred or nature kept them in check through periodic food shortages. A number of 20th-century hunter-gatherers have practiced infanticide and induced abortions to restrict the number and spacing of their children (Boserup 1981, 34). Constant travel by nomads may increase infant mortality and maternal mortality and produce more miscarriages than a sedentary life and thus keep the numbers in check. For primitive peoples, then, farming solved a major problem. Once

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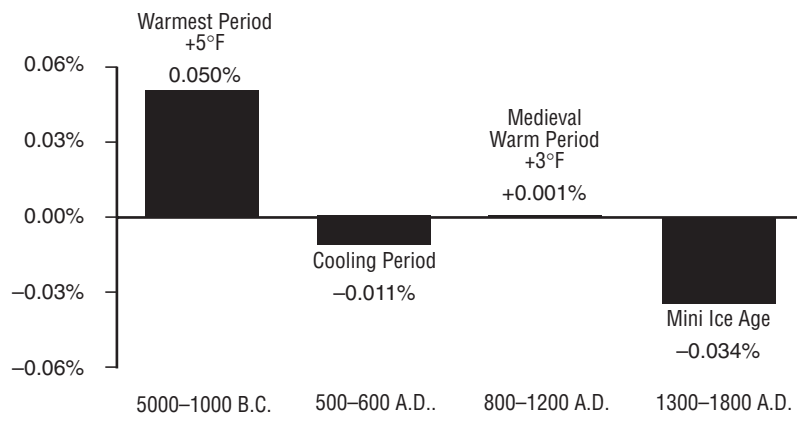
people settled down into fixed abodes, the population apparently ballooned.

Although many people view the current world's huge population with alarm, most ecologists take the size of the population of a species as an indicator of its fitness. By this criterion, the domestication of plants and animals improved greatly the fitness of *Homo sapiens*. This work is not the place to discuss the capacity of the globe to sustain the number of people expected to populate the world in the next century, but certainly anything that produced greater numbers of people thousands of years ago must have been beneficial for mankind.

Over history the number of humans has been expanding at ever more rapid rates. Around 25,000 years ago, the world's population may have measured only about 3 million (Kremer 1993, 683). Fifteen thousand years later, around 10,000 B.C., the total had grown by one-third to 4 million. It took 5,000 more years to jump one more million; but in the 1,000 years after 5000 B.C., another million were added. Except for a few disastrous periods, the number of men, women, and children has mounted with increasing rapidity. Only in the last few decades of the 20th century has the escalation slowed. Certainly there have been good times when man did better and poor times when people suffered—although in most cases those were regional problems. However, as Figure 2-1 shows, in propitious periods, that is, when the climate was warm, the population swelled faster than during less clement eras.

Figure 2-1 is based on a paper by economist Michael Kremer who argues that, until the Industrial Revolution, existing technology limited the size of the population (Kremer 1993, 681–716). As innovators discovered new techniques and invented new tools, more people could be fed and housed and the population expanded. Moreover, the greater the number of people, the more innovations would be hit upon. He assumed that every individual had an equal but very small probability of uncovering a new technique or device and that the probability of being an innovator was independent of the size of the population. Therefore, the number of inventions would be proportional to the number of people. Thus as the world population expanded—slowly at first—the rate of technological innovation escalated and hence the rate of growth of the population that could be sustained. Only in recent times has technological change become

*Figure 2-1*  
DIFFERENCE IN PERCENTAGE GROWTH RATE OF POPULATION  
FROM EXPECTED

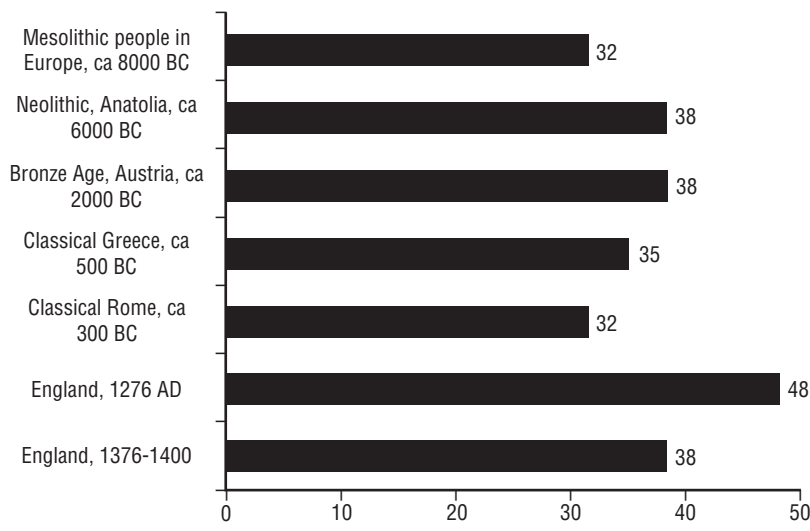


SOURCE: Kremer 1993, table 1; Moore, 1995.

so rapid that it has run ahead of population growth, leading to a rising standard of living, which in turn has reduced the birth rate.

Kremer’s hypothesis signifies that for most of history the rate of population growth should be proportional to the size of the population. To link his model and data with climate change, I started with his estimate of the world’s people in 10,000 B.C. and calculated the rate of growth of the population over the next 5,000 years. For each subsequent period, I also computed the rate of increase in numbers of people. Comparing the expected rates with actual growth revealed eras in which the number of humans has expanded faster than predicted and periods during which the world’s population has grown more slowly. The figure then shows the centuries in which the growth rate of the globe’s populace has exceeded or fallen short of the rate expected under this simple model. As can be seen, warm periods have done considerably better than cold periods in human expansion. The warmest period since the end of the last Ice Age produced the highest rate of population growth compared with what would have been expected—in that era agriculture was spreading. Moreover, the Mini Ice Age, which saw the coldest temperatures in the last 10,000 years, underwent the slowest relative population

Figure 2-2  
LIFE EXPECTANCY AT VARIOUS PERIODS



SOURCE: Lamb 1977, 264.

expansion. The figure demonstrates that mankind has prospered in warm periods and the hotter, the better!

Another measure of the well-being of humans is how long they live. The life of the hunter-gatherer was not as rosy as some have contended. Life was short—skeleton remains from before 8000 B.C. show that the average age of death for men was about 33 and that of women, 28 (Boserup 1981, 36–37). Death for men was frequently violent, while many women must have died in childbirth. Since women died so young, they had only around 13 years in which to bear children. Anthropologists have estimated that on average they could have given birth to fewer than five live babies, assuming that they bore a child every 22 months (Boserup 1981, 38). An infant and childhood mortality rate of about 60 percent would have kept the population stagnant.

Figure 2-2 shows some relevant data. People living during the warmest periods—the Neolithic, the Bronze Age, and England in the 13th century—enjoyed the longest life spans of the entire record. The shortening of lives from the late 13th to the late 14th century

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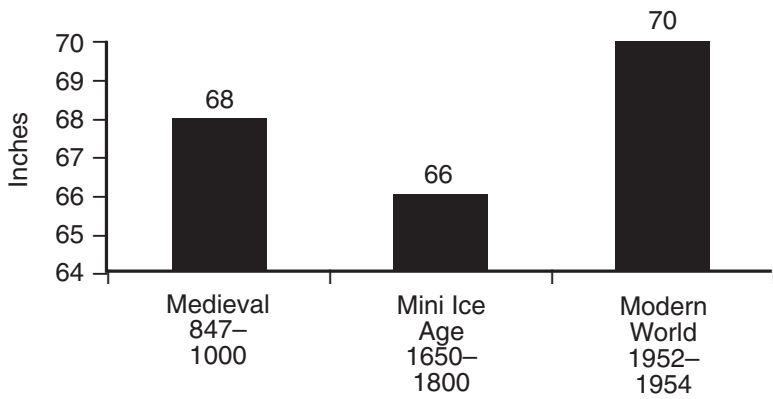
A.D. with the advent of much cooler weather is particularly notable. Moreover, the rise in life expectancies during the warm period could easily explain the population explosion that took place during that period.

Good childhood nutrition is reflected in taller adults. Skeleton remains collected over wide areas of Eurasia from the period when roving bands shifted from eating large animals and a few plants to smaller prey and a much wider variety of foods attest to a decline in height for both men and women of about five centimeters (two inches) (Cohen 1989, 112). The shorter stature came at the end of the Ice Age when large animals were disappearing. Some archaeologists have found that the average age of death for adults also declined during this transitional period (Cohen 1989, 113). Studies of bone chemistry from Middle Eastern skeletons indicate a reduction in meat consumption. The new diet, although more dependent on grains, fruits, and vegetables, must have been less nutritious than the old. As large game animals disappeared with the end of the Ice Age, humans widened the variety of plants in their diet, increasingly consuming vegetable matter that they had ignored for thousands of years because it was either less nutritious, more difficult to secure and process, or less tasty.

Research on American Indians before the arrival of Europeans also reveals a decline in health between early and later periods (Cohen 1989, 114–15). The evidence for the Americas is more mixed, however, than for Europe. On the basis of Eurasian studies and those of North American aborigines, it seems safe to conclude that health and nutrition were declining *before* the advent of agriculture; it may be that agriculture was invented to stave off further decreases in food availability. The absence of agriculture for most North American peoples may mean that game was more plentiful and their nutrition better than that of their European counterparts.

In southern Europe, the shift to agriculture coincides with a reduction in skeleton size of 3 centimeters (1.2 inches) for men and 4 centimeters (1.6 inches) for women (Cohen 1989, 119). Although some other archaeological studies have found that agriculture led to shorter people, a few have found the reverse. In Israel, for example, one study found that people grew taller with the domestication of animals (Cohen 1989, 119). Overall the evidence supports the view that the diet may have become less nutritious with the shift from

Figure 2-3  
AVERAGE HEIGHTS OF ICELANDIC MALES



SOURCE: Lamb 1977, 264.

large animal hunting to food production but that its quality initially exceeded that of medieval Europe. Figure 2-3, representing heights, however, signifies that food was more plentiful and better during the medieval period than during the Mini Ice Age.

In summary, the evidence supports overwhelmingly the proposition that during warm periods, humans prospered. They multiplied more rapidly; they lived longer; and they were apparently healthier. We now turn to a closer examination of the two major warm epochs.

### The First Climatic Optimum

About 9,000 to 4,000 years ago the earth was much warmer than today; perhaps 4°F hotter, about the average of the various predictions for global warming after a doubling of CO<sub>2</sub> (Lamb 1988, 22). Although the climate cooled a bit after 3000 B.C., it stayed relatively warmer than the modern world until some time after 1000 B.C., when chilly temperatures became more common. During this Climatic Optimum epoch, Europe enjoyed mild winters and warm summers with a storm belt far to the north. Not only was the region less subject to severe storms, but the skies were less cloudy and the days sunnier.

Notwithstanding the less stormy weather, rainfall was more than adequate to produce widespread forests. Western Europe, including

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parts of Iceland and the Highlands of Scotland, was mantled by great woods (Giles 1990, 133). The timber, until average temperatures dipped temporarily for about 400 years between 3500 B.C. and 3000 B.C., consisted of warmth-demanding trees, such as elms and linden in North America and oak and hazel in Europe. Those species have never regained their once dominant position in Europe and America. Not only did Europe enjoy a benign climate with adequate rainfall, but the Mediterranean littoral, including the Middle East, apparently received considerably more moisture than it does today (Claiborne 1970, 324). The Indian subcontinent and China were also much wetter during this Optimal period (Lamb 1982, 120).

As a senator, Al Gore, writing on the prospect of further global warming and its potential harm, contended that the temperature rise over the last century has led to increased drought in Africa (Gore 1992, 76). To bolster his argument, he presented a chart showing a decline in rainfall from 1930 to the early 1980s for portions of sub-Saharan Africa. His conclusion, however, is based on a false premise: for most of that period the earth was cooling, not warming! His chart actually implies that further cooling would be undesirable. In fact, history demonstrates and climatology attests that warming should drive the monsoon rains that originate near the equator farther north, possibly as far as the Sahara, contributing to a moister, not a drier, climate!

Compared with the cooler periods of the last few thousand years, the Sahara was much wetter and more fertile during the Climatic Optimum (Lamb 1988, 21). Cave paintings from the epoch depict hippopotamuses, elephants, crocodiles, antelopes, and even canoes (Giles 1990, 115–16). The water level in Lake Chad, about 14° north of the equator in central Africa, was some 30 to 40 meters, that is, 90 to 125 feet, higher than it is today, an indication of much greater precipitation. Ruins of ancient irrigation channels in Arabia, probably from the warmest millennia, indicate that they derived their water from sources well above current water supplies, attesting to a wetter climate (Lamb 1977, 270). A warming would likely lead to similar conditions, not a strengthening of African drought. With the cooling that started after 3000 B.C., North Africa dried up and the abundance of life disappeared.

Research has shown, however, that some portions of the globe did suffer from drier conditions. The Caspian Sea may have been

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at its lowest level in over 80,000 years during the warmest recent period—4,000 to 6,000 years ago—when it was some 20 to 22 meters—66 to 72 feet—below its modern height (Lamb 1977, 130).

The Southern Hemisphere seems to have flourished as well during the warm millennia after the most recent Ice Age. Professor Lamb reports that the southern temperate zone enjoyed both warmer weather and more moisture than it does currently (Lamb 1968, 61). Scholars have found that Australia was consistently wetter than today in both the tropical and temperate regions (Lamb 1982, 131). Since the end of that epoch, the great deserts of Australia have expanded and the climate has become both cooler and drier. Apparently most of the other great desert regions of the world enjoyed more rainfall during the Climatic Optimum than they do now. Lamb contends that the period of temperature maximum was also a period of moisture maximum in subtropical and tropical latitudes and a good period for forests in most temperate regions (Lamb 1982, 131). During that warm era, Hawaii experienced more rainfall than in the 20th century (Lamb 1968, 61). Even Antarctica enjoyed warmer weather, about 4° to 5°F higher than at present; during the summer in some of the mountains the weather was warm enough to produce running streams and lakes that have subsequently frozen (Lamb 1968, 62). Nevertheless, the basic ice sheet remained intact.

As already mentioned, the invention of agriculture coincided with the end of the last Ice Age and the melting of the glaciers. Archaeologists have found the earliest evidence for husbandry and farming in Mesopotamia around 9000 B.C. (Claiborne 1970, 243). As the earth warmed, the Middle East became wetter and the Iranian plateau shifted from an open dry plain with roving bands of game to a more wooded environment with less reliable food sources and a diminished supply of large animals. No one really knows how man first domesticated plants and animals; but the coincidence in time and the forcing nature of climate change suggest that the warmer, wetter weather (especially in the mountains) may have encouraged new techniques.

The transition from the Ice Age to a warmer climate that led eventually to agriculture is best documented in Europe. During the cold period, most of Europe was a dry plain, an open savanna, in which large herds of reindeer, mammoths, and bison roamed. As has been shown by the cave drawings in France and Spain, the

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population secured a good living by preying on those ungulates. As the climate warmed and as rainfall increased, forests spread north, limiting the habitat for the large mammals. Thus humans were forced to follow the dwindling herds northward or develop new sources of food. As the large animals disappeared, the local people shifted to exploiting red deer, wild boar, and smaller species. Those people located near the seas or large rivers found seafood a plentiful source of sustenance. On the other hand, people who made their living at the edge of the ocean faced seas that were rising about 3 feet each century and that often drowned them when high tides and storms washed over their primitive villages.

The domestication of plants appears to have occurred around the world at about the same time: from 10,000 B.P. to 7,500 B.P. (Ammerman and Cavalli-Sforza 1984, 16). The earliest well-documented employment of agriculture arose in the Middle East. Planting of wheat and barley began in southwest Asia between 8000 B.C. and 7000 B.C. In north China's Shensi Province between 4500 B.C. and 3500 B.C., peasants grew foxtail and millet and raised pigs. Food production in that part of China extends back at least into the sixth millennium B.C. In the Americas, domestication of some grains and chili peppers dates from between 7000 B.C. and 6000 B.C.; anthropologists have documented maize in the Tehuacan Valley by 5700 B.C. and production may have started earlier. In South America the evidence suggests that, in the Andean highlands, domestication of two species of beans as well as the chili pepper arose 8,500 years ago. Maize appears in the area only about 3000 B.C. In Africa the evidence implies the cultivation of plants after 3500 B.C. Domestication of cattle occurred in the Sahara about 8,000 years before the present (Ammerman and Cavalli-Sforza 1984, 14–16).

As Professors Ammerman and Cavalli-Sforza put it (1984, 16), "One of the few variables that would seem to be shared is timing: early experiments at plant domestication occurred in southwest Asia, east Asia, and Central America during the period between 8000 B.C. and 5500 B.C." The coincidence of the invention of agriculture with a general warming of the climate, an increase in rainfall, and a rise in carbon dioxide levels, all of which would have made plant growth more vigorous and more plentiful, cannot be accidental.

Domestication of plants and animals represented a fundamental shift in man's involvement with nature. Before that humans simply

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took what nature offered. People hunted or scavenged the local animals that happened their way. Women gathered fruits and vegetables that grew wild in their territory. With farming and herding, mankind, for the first time, began to modify the environment. Humans determined what would be grown, which plants would survive in their gardens, which animals would be cultivated and bred, and which would be shunned or eliminated. *Homo sapiens* ceased being simply another species that survived by predation coupled with grazing and became a manager of the environment.

The shift from a hunter-gatherer to a sedentary existence may be the most important innovation in human existence. Prior to this change, humans lived in small groups and moved frequently with the seasons to find new sources of meat, fruit, and vegetables. Being mobile meant carrying few goods and only those that were light and not fragile. Thus pottery, which is both heavy and easily breakable, was not part of their culture. Any musical instruments must have been small and portable. Many small children would have been a hindrance as would the elderly and the feeble. Such small groups would have had little opportunity to develop specialization. Virtually all males must have participated in the hunt while all females, not giving birth or caring for infants, must have helped gather edibles. Such tribal or family groups could not have supported elaborate priesthoods, bureaucratic governmental structures, or even people who specialized in artistic, cultural, or intellectual activities. As a consequence, the societies were probably quite egalitarian with only a few, such as the chief or elder and perhaps a medicine man, who stood out from the rest.

The development of agriculture and the establishment of fixed communities led to a population explosion and the founding of cities. Agricultural societies produce enough surplus to support such urban developments, including the evolution of trades and new occupations. A large community could afford to have specialists who made farm tools, crafted pots, and traded within the village and between the locals and outsiders. The people who established the first known city, Jericho, made an early step toward specialization—which lies at the heart of economic advancement—around 8000 B.C. (Lamb 1977, 256).

Farming required the development of property rights in lands, although pastures initially may have been held in common. Even

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though farm holdings in the beginning were probably fairly equally distributed, over time some families must have acquired larger holdings than others. The increase in income inequality may offend modern sensibilities, but it provided a major benefit. A wealthy class or a rich ruler could afford to maintain individuals who would create desirable objects, such as art, elaborate pots, and musical instruments, and who could record eclipses, star movements, or trade with other centers.

The taming of animals and plants also represents a movement toward establishing property rights. In a hunter-gatherer's world, no one owns the wild beasts or the fruit and grains until they are collected. This can work satisfactorily only as long as demands for the resources are limited. But as the literature on the tragedy of the commons shows, once pressures for more of anything grow too large, the resource base can be exhausted. In what is now called North America, many large species, such as horses, were apparently hunted to extinction. Domestication—privatization of animals and plants—became the answer to overhunting and overgrazing.

In Europe, the Climatic Optimum period produced an expansion of civilization witnessed by the construction of cities and a technological revolution. The Bronze Age replaced the New Stone Age (Lamb 1982, 126). The more benign climate with less severe storms encouraged travel by sea.

During the warm period, trade flourished. People from ancient Denmark shipped amber along the Atlantic coast to the Mediterranean. As early as 2000 B.C., the Celts were apparently sailing from Cornwall and Brittany to both Scandinavia and southern Italy. Astrological monuments built around this time, such as Stonehenge, indicate that the skies were less cloudy than now (Lamb 1977, 254). With the glaciers in the Alps during the late Bronze Age being only about 20 percent of the size of the ice in the 19th century, merchants made their way through the Brenner Pass, the dominant link between northern and southern Europe. Northern Europeans exchanged tin for manufactured bronze from the south. Alpine peoples mined gold and traded it for goods crafted around the Mediterranean. Baltic amber even found its way to Scotland.

During the warm period before 3000 B.C., China experienced much warmer temperatures. Midwinters, in particular, were as much as 9°F hotter and rice was planted a month earlier than is now common

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(Lamb 1982, 124). Bamboo, valued for food, building material, writing implements, furniture, and musical instruments, grew much farther north—about 3° in latitude—than is now possible (Ko-chen 1973, 228–29). Chinese archaeologists have found evidence in a district near Sian that the climate 5,000 to 6,000 years ago was warmer and wetter than in the present.

Prior to around 2500 to 1750 B.C., northwestern India, which is now very dry, enjoyed greater rainfall than it does in the 20th century (Lamb 1977, 251). In the Indus Valley, the Harappans created a thriving civilization that reached its apogee during the warmest and wettest periods, when their farmers were growing cereals in what is now a desert (Lamb 1977, 389). The area was well watered with many lakes. That civilization disappeared around 1500 B.C. at a time when the climate became distinctly drier (Claiborne 1970, 295). The earth was cooling. Historians and archaeologists also attribute the failure of the civilization to poor agricultural techniques that may have exacerbated drought.

Virtually all change can make some worse off, and the warming after the last Ice Age is no exception. Although most humans benefited, as the population explosion indicates, the growing warmth harmed some people, especially those who lived near the coast or who had earned their living hunting large animals. As the ice sheets melted, the sea level rose sharply and probably peaked around 2000 B.C. (Lamb 1977, 257, n. 1). During the many centuries in which the waters mounted, storms often led to ocean flooding of coastal communities. A few times each century, people were forced to abandon well-established villages and move to higher ground.

#### **Cooler, More Varied, and Stormy Times**

From the end of the Optimum period of sustained warmth until around A.D. 800 to 900, apparently the world's climate, particularly the European, varied between periods of warmth and cold. Based on the height of the upper tree lines in middle latitudes' mountains, temperatures, following the peak warm period around 5000 B.C., demonstrate a more or less steady decline lasting right up to the 20th century (Lamb 1982, 118, fig. 43). Tree ring data for New Zealand indicate that after temperatures reached a maximum around 6000 to 8000 B.C., the climate cooled in that part of the world. (McGlone et al. 1993, 311)

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After 1000 B.C. the climate in Europe and the Mediterranean cooled sharply and by 500 B.C. had reached modern average temperatures (Lamb 1988, 22). The period from 500 B.C. to A.D. 600 was one of varied warmth, although cooler on average than the previous 4,500 years. However, the climate became more clement and somewhat more stable from 100 B.C. to A.D. 400, the period of the Roman Empire (Lamb 1988, 23). The Italians grew grapes and olives farther north than they had before that period. During those centuries of varied weather, Classical Greece flourished and then declined; the Roman Empire spread its authority through much of what is now Europe, the Middle East, and North Africa, only to be overrun by barbarians from central Asia whose eruption out of their homeland may have been brought on by a change in the climate.

The cooler climate after the start of the last millennium B.C. appears to have contributed to a southerly migration of people from northern Europe (Lamb 1977, 419). Archaeologists have also found evidence that Greeks adopted warmer clothing after 1300 B.C. The population living in the Alps diminished sharply with the cooler weather, and mining ceased. Classical historian Ray Carpenter (1966) attributes a depopulation of Greece and Turkey between 1200 and 750 B.C. to long-term drought that must have reflected the increased coolness of the climate.

Evidence for a cooler Mediterranean climate from 600 B.C. to 100 B.C. comes from remains of ancient harbors at Naples and in the Adriatic that are located about one meter (three feet) below current water levels (Lamb 1977, 257). Further support for lower sea levels has been found on the North African coast and around the Aegean, the Crimea, and the eastern Mediterranean. Lower oceans imply a colder world, leading to a buildup of snow and ice at the poles and in major mountain glaciers. By A.D. 400, however, temperatures had warmed enough to raise water levels to about three feet above current elevations. The ancient harbors of Rome and Ravenna from the time of the Roman Empire are now located about one kilometer from the sea (Lamb 1977, 258). Evidence exists for a peak in ocean heights in the fourth century A.D. for points as remote as Brazil, Ceylon, Crete, England, and the Netherlands, indicating a world-wide warming.

Changes in the climate in Eurasia appear to have played a major role in the waves of conquering horsemen who rode out of the plains

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of central Asia into China and Europe. Near the end of the Roman Empire, around A.D. 300, the climate began to warm and conditions in central Asia improved, leading apparently to a population explosion (Claiborne 1970, 344–47). These people, needing room to expand and a way to make a living, invaded the more civilized societies of China and the West. The medieval warmth from around A.D. 1000 to 1300 also seems to have triggered an expansion from that area. During this second optimum period, the homeland of the Khazars centered around the Caspian Sea enjoyed much greater rainfall than earlier or than it does now. The increased prosperity in this area produced a rapidly rising number of young men who provided the manpower for Genghis Khan to invade China and India and to terrorize Russia and the Middle East (Lamb 1977, 250).

After A.D. 550 until around 800, Europe suffered through a colder, wetter, and more stormy period. As the weather became wetter, peat bogs formed in northern areas (Lamb 1968, 63). The population abandoned many lakeside dwellings while mountain passes became choked with ice and snow, making transportation between northern Europe and the south difficult. The Mediterranean littoral and North Africa dried up, although they remained moister than now.

Inhabitants of the British Isles between the 7th and the 9th centuries were often crippled with arthritis while their predecessors during the warmer Bronze Age suffered little from such an affliction. Although some archaeologists have attributed the difficulties of the people during those centuries to harder work, the cold, wet climate between A.D. 600 and 1000 may have fostered such ailments (Lamb 1977, 261).

During the centuries after the fall of the Roman Empire and with the deterioration of the climate, Greece languished. In A.D. 542, the population was decimated by the plague, aggravated by cold, damp conditions; the Black Death struck again between 744 and 747 (Cheetham 1981, 18, 20). As a consequence the number of people was sharply reduced. Greece was partially repopulated in the 9th and 10th centuries when the Byzantine Emperors brought Greek settlers from Asia Minor back into the area. For the first time in centuries Greek commerce and prosperity returned—probably because of an improved climate (Cheetham 1981, 26).

In the 9th century, land hunger and a rising population in Norway and Sweden spurred the Scandinavians to loot and pillage by sea.

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Their first descent was on the monastery of Lindisfarne in northern England in 793. That was followed by raids on Seville in Muslim Spain in 844 and later farther into the Mediterranean (Keegan 1993, 288). In the latter half of the 9th century the Scandinavians discovered Iceland and in the next century, Greenland. In 877 they began an invasion of England and conquered from the north to the whole of the Midlands—all of which became a Danish overseas kingdom by the mid-10th century. At the same time, they stormed France and the king had to cede them Normandy as a fief. They also crossed the Baltic (known as Rus in that time) and sent traders south to the Middle East and Byzantium.

### **The High Middle Ages and Medieval Warmth**

From around A.D. 800 to 1200 or 1300, the world warmed considerably and civilization prospered. The period, called the Little Climate Optimum, generally displays, although less distinctly, many of the same characteristics as the first climate optimum (Lamb 1968, 64). Virtually all of northern Europe, Britain, Ireland, Greenland, and Iceland were considerably warmer than at present. The Mediterranean, the Near East, the Arabian peninsula, and North Africa, including the Sahara, received more rainfall than they do today (Lamb 1968, 64–65). North America enjoyed better weather during most of the period. In the early part of that epoch, China experienced higher temperatures and a more clement climate. From Western Europe to China, East Asia, India, and the Americas, mankind flourished as never before.

Evidence for the medieval warming comes from contemporaneous reports on weather conditions, from oxygen isotope measurements taken from the Greenland ice, from upper tree lines in Europe, and from sea level changes. They all point to a more benign, warmer climate with more rainfall; but because of more evaporation, less standing water. Not only did northern Europe enjoy more rainfall but the Mediterranean littoral was wetter. An early 12th-century bridge with 12 arches that still exists over the river Oreto at Palermo exceeds the needs of the small trickle of water that flows there now (Lamb 1968, 8). According to Arab geographers, two rivers in Sicily that are too small for boats today were navigable during that period (Lamb 1977, 271). In England at the same time, medieval water mills on streams that today carry too little water to turn them attest to

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greater rainfall. Although England apparently received more rainfall than in modern times, the warm weather led to more drying out of the land. Support for a more temperate climate in central Europe comes from the period in which German colonists founded villages. As average temperatures rose, people established towns at higher elevations. Early settlements were under 650 feet in altitude; those from a later period were between 1,000 and 1,300 feet high; those built after 1100 A.D. were located above 1,300 feet (Bartlett 1993, 162).

The great historian of climate, H. H. Lamb, counted manuscript reports of flooding and wet years in Italy (Lamb 1977, 427). He discovered that starting in the latter part of the 10th century, the number of wet years climbed steadily, reaching a peak around 1300 A.D. Over the same period, northern Europe was enjoying warmer and more clement weather. Not only was the temperature higher than now in Europe during the 12th and 13th centuries but the population enjoyed mild, wet winters. In the Mediterranean it was moist as well, with frequent reports of summer thunderstorms (Lamb 1977, 429).

Studies have shown that some areas became drier during those centuries. In particular, the Caspian Sea was apparently four meters—over 13 feet—lower from the 9th through the 11th century than currently (Lamb 1977, 133). After A.D. 1200 the elevation of the sea rose sharply for the next 200 or 300 years ((Lamb 1977, 439). In the Asian steppes, warm periods with fine summers and often with little snow in the winters produced water levels that were low by modern standards (Lamb 1977, 136). A recent study of tree rings from areas as widely distant as California's Sierra Nevada and Patagonia concluded that the "Golden State" endured extreme droughts from around 900 to 1100 and again from 1210 to 1350 A.D., while the tip of South America during the first 200 years also suffered from little precipitation (Stine 1994, 546–49).

The timing of the medieval warm spell, which lasted no more than 300 years, was not synchronous around the globe. For much of North America, for Greenland, and in Russia, the climate was warmer between 950 and 1200 A.D. (Lamb 1977, 435). The warmest period in Europe appears to have come later, roughly between 1150 and 1300 A.D., although parts of the 10th century were quite warm. Evidence from New Zealand indicates peak temperatures from 1200 to 1400 A.D.

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Data on the Far East are meager but mixed. Judging from the number of severe winters reported by century in China, the climate was somewhat warmer than normal in the 9th, 10th, and 11th centuries, cold in the 12th and 13th, and very cold in the 14th. Chinese scholar Chu Ko-chen reports that the 8th and 9th centuries were warmer and received more rainfall but that the climate deteriorated significantly in the 12th century (Ko-chen 1973, 235). He found records, however, that show that the first half of the 13th century was quite clement; very cold weather returned in the 14th century (Ko-chen 1973, 237–38). On the basis of records of major floods and droughts, another historian found that between the 9th and 11th centuries China suffered many fewer of these calamities than during the 14th through the 17th (Chao 1986, 203).

The evidence for Japan is based on records of the average April day on which the cherry trees bloomed in the royal gardens in Kyoto. From this record, the 10th century springs were warmer than normal; in the 11th century springs were cooler; the 12th century experienced the latest springs; the 13th century was average and the 14th was again colder than normal (Lamb 1977, 443, 447, tables 17-3,17-4). That record suggests that the Little Climate Optimum began in Asia in the 8th or 9th centuries and continued into the 11th. The warm climate moved west, reaching Russia and central Asia in the 10th through the 11th, and Europe from the 12th to the 14th. Some climatologists have theorized that the Mini Ice Age also started in the Far East in the 12th century and spread westward, reaching Europe in the 14th (Ko-chen 1973, 239–40).

### *Europe*

The warm period coincided with an upsurge of population almost everywhere, but the only numbers are for Europe. For centuries during the cold, damp “Dark Ages,” the population of Europe had been relatively stagnant. Towns shrank to a few houses clustered behind city walls. Although we lack census data, the figures from Western Europe after the climate improved show that cities grew in size; new towns were founded; and colonists moved into relatively unpopulated areas.

Historians have failed to agree on why, after the 11th century, the population soared. It may be more enlightening to ask why the population remained stagnant for so long. As John Keegan (1993,

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149), the eminent military historian, put it: “The mysterious revival of trade between 1100 and 1300, itself perhaps due to an equally mysterious rise in the European population from about 40,000,000 to about 60,000,000, in turn revived the life of towns, which through the growth of a money economy won the funds to protect themselves from dangers beyond the walls.”

Although it is impossible to document, the change in climate from cold and wet to warm and drier—it had more rainfall, but more evaporation reduced bogs and marshy areas—seems likely to have played a significant role. In the 8th through the 11th centuries, most people spent considerable time in dank hovels, avoiding the inclement weather. Those conditions were ripe for the spread of disease. Tuberculosis, malaria, influenza, and pneumonia undoubtedly took many small children and the elderly—those over 30.

Written records confirm that the warmer climate brought drier and consequently healthier conditions to much of Europe. Robert Bartlett (1993, 155) quotes H. E. Hallam in *Settlement and Society* about the people of Holland who invaded Lincolnshire in 1189: “Because their own marshes had dried up, they converted them into good and fertile ploughland.” Moreover, before the 12th century German settlers on the east side of the Elbe frequently ended the names of their towns with *mar*, meaning marsh, but later colonists did not use that suffix. Bartlett (1993, 162) explains that the term had gone out of use, but an alternative explanation is that the warmer climate had dried up the marshes.

With a more pleasant climate, people spent longer periods outdoors; food supplies were more reliable. Even the homes of the peasants would have become warmer and less damp. The draining or drying up of marshes and wetlands reduced the breeding grounds for mosquitoes that brought malaria. Overall the infant and childhood mortality rate must have fallen, spawning an explosion in population.

From the 9th century, with a climate still quite cool, to the 11th, medieval Europe was almost totally agricultural. The few cities that existed consisted mainly of religious seats with their support personnel. Even as late as the 12th century, city dwellers made up less than 10 percent of the population (Pirenne, c. 1938, 59). Trade before the 11th century was virtually nonexistent (Pirenne, c. 1938, 12). People were tied to the land through custom and necessity. The

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great feudal estates grew what they ate and ate what they grew; they wove their own cloth and sewed their own clothes; they built what little furniture was needed. In short, they were almost entirely self-sufficient. The serfs that tilled the land had inherited rights to enough land to sustain a family. Typically the older son would follow his father. Other sons either joined the priesthood or became monks, vagabonds, or in later centuries, mercenaries. Given the cold climate before the 11th century, the lack of medical care, and a restricted diet fostering poor nutrition, few babies lived to adulthood. The problem of an excess of labor was, therefore, nonexistent. In truth the population was growing so slowly that a labor shortage persisted and the feudal nobility established laws prohibiting serfs from leaving their land.

Until the 12th century when the weather became significantly more benign, a Europe fettered by tradition remained cloistered in self-sufficient units. The next two centuries, however, witnessed a profound revolution that, by the end of the 13th century, transformed the landscape into an economy filled with merchants, vibrant towns, and great fairs. Crop failures became less frequent; new territories were brought under control. With a more clement climate and a more reliable food supply, the population mushroomed. Even with the additional arable land permitted by a warmer climate, the expansion in the number of mouths exceeded farm output: food prices rose while real wages fell. Farmers, however, did well with more ground under cultivation and low wages payable to farm hands (Donkin 1973, 90).

Although the first sons born on the estates could follow their fathers, other children, especially the men, had to find new opportunities. The Crusades furnished an occasion for the sons both of serfs and of the nobility to enrich themselves and even to find new land to cultivate. Others moved to virgin territory in eastern Europe, Scandinavia, or previously forested or swampy areas (Bartlett 1993, ch. 6). The Franks and Normans launched invasions of England, southern Italy, Byzantine Greece, and the eastern Mediterranean. In 1130 the Tancred de Hauteville clan, a notable example, founded the Kingdom of Sicily. That family, a classic case of "over-breeding, land-hungry lesser nobility," consisted of 12 sons from two mothers who, recognizing that their Norman property was inadequate, invaded southern Italy in search of land and riches (Bartlett 1993, 48).

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During the High Middle Ages, the Germans advanced across the Elbe to take land from pagan Serbs. The spread of knights and soldiers out of France and Germany demonstrates that the population was multiplying more rapidly in northern Europe than in southern. The rapid rise in numbers north of the Alps fits the improved climatic scenario: global or continental warming brought greater temperature change and more beneficial weather to higher latitudes.

The more skilled and enterprising who did not seek their fortune in foreign lands typically flocked to towns and urban centers, becoming laborers, artisans, or traders. Those who moved to the new cities and those who founded colonies were both legally freed of feudal obligations. That new liberty, making risk-taking and innovation possible, was essential for those in commerce.

The warmth of the Little Climate Optimum made territory farther north cultivable. In Scandinavia, Iceland, Scotland, and the high country of England and Wales, farming became common in regions that neither before nor since have yielded crops reliably. In Iceland, oats and barley were cultivated. In Norway, farmers planted farther north and higher up hillsides than at any time for centuries. Greenland savored weather that was 4° to 7°F warmer than at present; settlers could bury their dead in ground that is now permanently frozen. Scotland flourished during the warm period with increased prosperity and construction (Lamb 1977, 437). Greater crop production meant that more people could be fed, and the population of Scandinavia exploded (Claiborne 1970, 348–64). The rapid growth in numbers in turn propelled and sustained the Viking explorations and led to the foundation of colonies in Iceland and Greenland.

The increasingly warm climate was reflected in a rising sea level. People were driven out of the lowlands and there was a large-scale migration of men and women from those areas to places east of the Elbe and into Wales, Ireland, and Scotland. Flemish dikes to hold back the sea date at least from the early 11th century. Although Pirenne and Bartlett attribute them to attempts to reclaim land from the sea to provide new areas for farming, the evidence points toward a climbing water level that farmers in the Low Countries had to battle (Pirenne, c. 1938, 76; Bartlett 1993, 114–15). The earliest texts setting out rights on the reclaimed land fail to mention any obligation to maintain the dikes, although later ones spell out the requirement, suggesting that the problem of holding back the sea became worse

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over time. Robert Bartlett quotes from a Welsh chronicle on the influx of people from Flanders:

that folk, as is said, had come from Flanders, their land, which is situated close to the sea of the Britons, because the sea had taken and overwhelmed their land . . . after they had failed to find a place to live in—for the sea had overflowed the coast lands, and the mountains [sic] were full of people so that it was not possible for everyone to live together there because of the multitude of the people and the smallness of the land (Bartlett 1993, 115).

In addition to the land north of the Alps, the warmer, rainier climate benefited southern Europe, especially Greece, Sicily, and southern Italy. All of the *Mezzogiorno* in the Middle Ages did well (Cheetham 1981, 37). Nicolas Cheetham, a former British diplomat who wrote a recent book, *Mediaeval Greece*, reports that during the first half of the 13th century, the plains and valleys of the Peloponnese were fertile and planted with a wide variety of valuable crops and trees. They produced wheat, olives, fruit, honey, cochineal for dyeing, flax for the linen industry, and silk from mulberry trees. The wealthy in Constantinople prized highly the wines, olives, and fruit from Greece. Thessaly's grain fed the Byzantine Empire (Cheetham 1981, 28). Patras exported textiles and silk of very high quality. Extensive forests full of game supplied acorns for hordes of pigs. Herders raised sheep and goats in the mountain pastures, while in the valleys farmers kept horses and cattle (Cheetham 1981, 85).

The Mediterranean flourished in the 12th century. Christian and Muslim lands achieved great brilliance. Cordova, Palermo, Constantinople, and Cairo all thrived, engendering great tolerance for contending religions (Cheetham 1981, 35–36). Christian communities survived and prospered in Muslim Cairo and Cordova. The rulers of Byzantium countenanced the followers of Mohammed and often preferred them to “barbaric” Westerners.

In the West, Charlemagne, creator of the Holy Roman Empire, may have inaugurated the era of the High Middle Ages while Dante, writing *The Divine Comedy*, may have closed it. In *A History of Knowledge*, Charles Van Doren (1991, 111) contends that “the . . . three centuries, from about 1000 to about 1300, became one of the most optimistic, prosperous, and progressive periods in European history.” All across Europe, the population went on an unparalleled

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building spree, erecting at huge cost spectacular cathedrals and public edifices. Byzantine churches gave way to Romanesque, to be replaced in the 12th century by Gothic cathedrals. During the period construction began on the Abbey of Mont-Saint-Michel (1017), St. Mark in Venice (1043), Westminster Abbey in London (1045), the Cathedral of our Lady in Coutances (1056), the Leaning Tower at Pisa (1067), the Cathedral of Santiago de Compostela in northern Spain (1078), the Cathedral of Modena (1099), Vézelay Abbey in France (1130), Notre-Dame in Paris (1163), Canterbury in England (1175), Chartres (1194), Rouen's cathedral in France (1201), Burgos' cathedral in Castile (1220), the basilica of Saint Francis in Assisi (1228), the Sainte Chapelle in Paris (1246), Cologne Cathedral (1248), and the Duomo in Florence (1298). Virtually all the magnificent religious edifices that we visit in awe today were started by the optimistic populations of the 11th through the 13th centuries, although many were not finished for centuries. In southern Spain, the Moors laid the cornerstone in 1248 for perhaps the world's most beautiful fortress, the Alhambra. Also in the middle of the 13th century, the Franks founded a fort, Mistra, near ancient Sparta, which later became a Byzantine city known for its art and culture.

It took a prosperous society to launch such major architectural projects. In Europe, building the cathedrals required a large and largely experienced pool of labor. During the week of June 23 to June 29, 1253, the accounts of the construction at Westminster Abbey, for example, show 428 men on the job, including 53 stonemasons, 49 monumental masons, 28 carpenters, 14 glassmakers, 4 roofers, and 220 simple laborers (Gimpel 1983, 68, table). Nearly half of all workers were skilled specialists. Even during the slowest season in November, the Abbey employed 100 workers, including 34 stonemasons. Masons and stonemasons earned the highest wages and usually hired a number of workers as assistants. Master craftsmen moved from job to job around Europe without any concern about national borders—the first truly European Community. Historians have found that only 5 to 10 percent of the masons and stonemasons were local people, whereas 85 percent of the men who quarried the stones—an unhealthy and arduous job—were from the vicinity (Gimpel 1983, 69).

Economic activity blossomed throughout the Continent. Banking, insurance, and finance developed; a money economy became well

established; manufacturing of textiles expanded to levels never seen before. Farmers were clearing forests, draining swamps, and expanding food production to new areas (Bartlett 1993, 2). The building spree mentioned was made possible by low wages resulting from a population explosion and by the riches that the new merchant classes were creating. In England, virtually all the churches and chapels that had originally been built of wood were reconstructed in stone between the 12th and 14th centuries (Donkin 1973, 110–11). With the clergy still opposing buying and selling for gain, those who became wealthy often constructed churches or willed their estates or much of them to religious institutions as acts of redemption (Pirenne c. 1938, 50). In that way they supplied much of the funding needed to erect the great Gothic cathedrals.

Starting in the 11th century, European traders developed great fairs that brought together merchants from all over Europe. At their peak in the 13th century, they were located on all the main trade routes and not only served to facilitate the buying and selling of all types of goods but also functioned as major money markets and clearing-houses for financial transactions. The 14th century saw the waning of those enterprises, probably because the weather became so unreliable and poor that transport to and from these locations with great stocks of goods became impractical. Belgian historian Henri Pirenne attributes their decline to war, which may indeed have played a role; but the failure of crops and the increased wetness must have made travel considerably more difficult (Pirenne c. 1938, 103). Wet roads became muddy tracks, rendering the transport of heavy goods arduous. Crop failures made for famines and more vagabonds who preyed on travelers.

During the High Middle Ages of the 12th and 13th centuries, technology grew rapidly. New techniques expanded the use of the water mill, the windmill, and coal for energy and heat. Sailing improved through the invention of the lateen sail, the sternpost rudder, and the compass. Governments constructed roads and contractors developed new techniques for use of stone in construction. New iron-casting techniques led to better tools and weapons. The textile industry began employing wool, linen, cotton, and silk and, in the 13th century, developed the spinning wheel. Soap, an essential for hygiene, came into use in the 12th century. Mining, which had declined since the Romans, at least partly because the cold and snow made access to mountain areas difficult, revived after the 10th century.

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Farmers and peasants in medieval England launched a thriving wine industry south of Manchester. Good wines demand warm springs free of frosts, substantial summer warmth and sunshine without too much rain, and sunny days in the fall. Winters cannot be too cold—not below zero Fahrenheit for any significant period. The northern limit for grapes during the Middle Ages was about 300 miles above the current commercial wine areas in France and Germany. The wines were not simply marginal supplies but of sufficient quality and quantity that, after the Norman conquest, the French monarchy tried to prohibit British wine production (Lamb 1977, 277). From average and extreme temperatures in the most northern current wine-growing regions of France and Germany compared with current temperatures in the former wine-growing regions in England, Lamb calculates that the temperature in spring and summer was somewhere between 0.9° and 3.4°F warmer in the Middle Ages (1977, 278–79).

Not only did the British produce wines during the Little Climate Optimum but farmers grew grapes in East Prussia, Tilsit, and south Norway (Lamb 1977, 279). Many areas cultivated in Europe were much farther up mountains than is possible under the modern climate. Together those factors suggest that the temperatures in central Europe were about 1.8° to 2.5°F higher than during the 20th century.

Europe's riches and a surplus of labor enabled and emboldened its rulers to take on the conquest of the Holy Land through a series of Crusades starting in 1096 and ending in 1291 A.D. The Crusades, stimulated at least in part by a mushrooming population and an economic surplus large enough to spare men to invade the then Muslim empire, captured Jerusalem in 1099—a feat not equaled until the 19th century. A major attraction of the first Crusade was the promise of land in a "southern climate" (Keegan 1993, 291).

Even southern Europe around the Mediterranean enjoyed a more moist climate than currently (Lamb 1968, 8). In the reign of the Byzantine emperor Manuel I Comnenus, art and culture flourished and all the world looked to Constantinople as its leader (Langer 1968, 269). Under the control of the Fatimid caliphate, Egypt cultivated a "House of Science" where scholars worked on optics, compiled an encyclopedia of natural history, with a depiction of the first known windmills, and described the circulation of the blood. In Egypt, block-printing appeared for the first time in the West (Langer 1968,

206, 286). The caliphate turned Cairo into a brilliant center of Islamic culture. In Persia (today's Iran), Omar Khayyam published astronomical tables, a revision of the Muslim calendar, a treatise on algebra, and his famous *Rubáiyát* (Carruth 1993, 161).

As European commerce expanded, traders reached the Middle East, bringing back not only exotic goods but new ideas and information about classical times. Drawing on fresh information about Aristotelian logic, St. Thomas Aquinas defined medieval Christian doctrine in his *Summa Theologica*. Possibly the oldest continuous university in the world was founded in Bologna in A.D. 1000 for the study of the law. Early in the 12th century a group of scholars, under a license granted by the chancellor of Notre-Dame, began to teach logic, thus inaugurating the University of Paris. Cambridge University traces its foundation to 1209 and Oxford to slightly later in the 13th century. Roger Bacon, one of the first to put forward the importance of experimentation and careful research, studied and taught at Oxford in the 13th century.

Secular writing began to appear throughout northern Europe. In the 12th century the medieval epic of chivalry, the *Chanson de Roland*, was put into writing. Between 1200 and 1220 an anonymous French poet composed the delightful and optimistic masterpiece *Aucassin et Nicolette*. An anonymous Austrian wrote in Middle High German the *Nibelungenlied* (Carruth 1993, 134, 170, 171).

#### *The Arctic*

From the 9th through the 13th centuries agriculture spread into northern Europe and Russia where it had been too cold to produce food before. In the Far East, Chinese and Japanese farmers migrated north into Manchuria, the Amur Valley, and northern Japan (McNeill 1963, 559). As mentioned, the Vikings founded colonies in Iceland and Greenland, a region that may have been more green than historians have claimed. It was also during this period that Scandinavian seafarers discovered "Vinland"—somewhere along the East Coast of North America. The subsequent Mini Ice Age cut off the colonies in Greenland from Europe, and they eventually died off. Even today, during this warm period of the late 20th century, the British climate forecloses large-scale grape production and Greenland is unsuitable for farming.

The Eskimos apparently expanded throughout the Arctic area during the medieval warm epoch (Lamb 1977, 248). Starting with

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Ellesmere Land around A.D. 900, Eskimo bands and their culture spread from the Bering Sea into the Siberian Arctic. Two centuries later, they migrated along the coast of Alaska and into Greenland. During that period the Eskimos' main means of livelihood was whaling, which had to be abandoned with the subsequent cooling. The Mini Ice Age forced the Thule Eskimos south out of northern Alaska and Greenland. Those hardy aborigines had abandoned Ellesmere Land by the 16th century.

At the same time that the Eskimos were moving north, Viking explorers were venturing into Greenland, Vinland, and even the Canadian Arctic. Scandinavian sailors found Iceland in 860, Greenland around 930, and North America by 986 (Lamb 1977, 252). By the turn of the millennium, when the waters southwest of Greenland may have been at least 7°F warmer than now, Vikings were regularly visiting Vinland for timber (Lamb 1988, 159). They were received with great hostility by the natives and eventually abandoned contact, although the last trip may have occurred as late as 1347, when a Greenland ship was blown off course (Lamb 1977, 252). At the height of the warm period, Greenlanders were growing corn and a few cultivated grain.

#### *The Far East*

As noted above, the warming in the Far East seems to have preceded that in Europe by about two centuries. Chinese economist Kang Chao has studied the economic performance of China since 200 B.C. In his careful investigation, he discovers that real earnings rose from the Han period (206 B.C. to A.D. 220) to a peak during the Northern Sung Dynasty (A.D. 961 to 1127) (Chao 1986, 219). This coincides with other evidence of longer growing seasons and a warmer climate. He explains the fall in worker productivity after the 12th century as stemming from population pressures, but a change in climate may have played a significant role. Chao reports that the number of major floods averaged fewer than four per century in the warm period of the 9th through the 11th centuries while the average number was more than double that figure in the 14th through the 17th centuries of the Mini Ice Age (Chao 1986, 203). Not only floods but droughts were less common during the warm period. The era of benign climate sustained about three major droughts per century while during the later cold period, China suffered from almost 13 each 100 years.

The wealth of the period gave rise to a great flowering of art, writing, and science. The Little Climate Optimum witnessed the highest rate of technological advance in Chinese history. During the 300 years of the Sung Dynasty, farmers invented 35 major agricultural implements—that is, over 11 per century, a significantly higher rate of invention than in any other era (Chao 1986, 195). In the middle of the 11th century A.D., the Chinese became the first to employ movable type (Carruth 1993, 151).

During the Northern Sung Dynasty Chinese landscape painting with its exquisite detail and color reached its apogee (Langer 1968, 366). Adam Kessler, curator of the Los Angeles County Museum of Natural History, dates the earliest Chinese blue-and-white porcelain to the 12th century (Kessler 1994, A17). The Southern Sung produced pottery and porcelains unequalled in subtlety and sophistication. Literature, history, and scholarship flourished as well. Scholars prepared two great encyclopedias, compiled a history of China, and composed essays and poems. Mathematicians developed the properties of the circle. Astronomers devised a number of technological improvements to increase the accuracy of measuring the stars and the year (Langer 1968, 367).

Japan also prospered during the Little Climate Optimum. In the Heian Period (A.D. 794 to 1192) the arts thrived as emperors and empresses commissioned vast numbers of Buddhist temples. Murasaki Shikibu, perhaps the world's first female novelist, composed Japan's most famous book, *The Tale of Genji*. Other classical writers penned essays: Sei Shonagon, another lady of the court, wrote *Makura-no-Soshi* (the Pillow Book). The Japanese aristocracy vied in composing the best poems. All of this attests a prosperous economy with ample food stocks to support a leisured and cultivated upper class.

Over the 400 years between A.D. 800 and 1200, the peoples of the Indian subcontinent prospered as well. Society was rich enough to produce colossal and impressive temples, beautiful sculpture, and elaborate carvings, many of which survive to this day (McNeill 1963, 559). The Lingaraja Temple, one of the finest Hindu shrines, as well as the Shiva Temple date from this period (Carruth 1993, 151). Seafaring empires existed in Java and Sumatra, which reached its height around 1180. Ninth century Java erected the vast stupa of Borobudur; other temples—the Medut, Pawon, Kelasan, and Prambanan—originated in this era. In the early 12th century, the predecessors of the Cambodians, the Khmers, built the magnificent temple of Angkor Wat (Langer

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1968, 372). In the 11th century Burmese civilization reached a pinnacle. In or around its capital, Pagan, between 931 and 1284, succeeding kings competed in constructing vast numbers of sacred monuments and even a library (Deland 1987, 9, 29–32). Today the area is a dusty plain littered with the crumbling remains of about 13,000 temples and pagodas built in a more hospitable era.

Archaeologists studying the composition of forests in New Zealand have found that the South Island enjoyed a warmer climate between A.D. 700 and 1400, about the time that Polynesians were colonizing the South Pacific Islands and the Maoris were settling in New Zealand (Lamb 1977, 430–31). Partially confirming that warming are data from Tasmania of tree rings that show a warm period from A.D. 940 to 1000 and another from 1100 to 1190 (Cook et al. 1991, 1267).

#### *The Americas*

Less is known about civilizations in the Americas during the Little Climate Optimum or even how the prevailing weather changed. Many of the currently arid areas of North America were apparently wetter during that epoch. The Great Plains east of the Rocky Mountains, the upper Mississippi Valley, and the Southwest received more rainfall between A.D. 800 and 1200 than they do now (Lamb 1988, 42). Radiocarbon dating of tree rings indicates that warmth extended from New Mexico to northern Canada. In Canada, forests extended about 60 miles north of their current limit (Lamb 1988, 42).

Starting around A.D. 800 to 900, the indigenous peoples of North America extended their agriculture northward up the Mississippi, Missouri, and Illinois river basins. By 1000 they were farming in southwestern and western Wisconsin and eastern Minnesota (Lamb 1977, 249). They grew corn in northwestern Iowa prior to 1200 in an area that is now marginal for rainfall (Lamb 1982, 177). When colder, drier weather set in after 1150 to 1200 A.D., Indian settlements on the northern plains of Iowa were abandoned. After that time, the natives substituted bison hunting for growing crops. In general, the land east of the Rocky Mountains enjoyed wetter conditions from 700 to 1200 A.D. and then turned drier as colder Arctic weather intruded more frequently.

The Anasazi civilization of Mesa Verde flourished during the warm period, but the cooling of the climate around 1280 A.D., at the

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end of the medieval warmth, probably led to its disappearance (Gore 1992, 78). That climatic shift brought drier conditions to much of the region, leading to a retreat from the territory and forcing the Pueblo Indians to shift their farming to the edge of the Rio Grande.

Around 900, the Chimu Indians in South America developed an extensive irrigation system on Peru's coast to feed their capital of between 100,000 to 200,000 souls, a huge number for the era (Carruth 1993, 142–43). The Toltec civilization, which occupied much of Mexico, reached its apogee in the 13th century (Langer 1968, 386). By 1200, the Aztecs had built the pyramid of Quetzalcoatl near modern Mexico City (Carruth 1993, 168). The Mayan civilization, however, reached a peak somewhat earlier, before 1000, and declined subsequently for reasons that remain unclear. It is possible that the warming after 1000 led to additional rainfall in the Yucatán, making the jungle too vigorous to restrain and causing a decline in farming, while at the same time improving agricultural conditions in the Mexican highlands and farther north into what is now the southwestern United States.

Thus warmer times brought benefits to most people and most regions, but not all. As is always the case with a climatic shift, the changes benefited some while affecting other adversely. Change is disruptive; at the same time it produces new ideas and new ways of coping with the world. Nevertheless, for most of the known globe, the Little Climate Optimum of the 9th through the 13th centuries brought significant benefits to the local populations. Compared with the subsequent cooling, it was nirvana.

### **The Mini Ice Age**

The Little Ice Age is even less well defined than the medieval warm period. Climatologists are generally agreed that, at least in Europe, North America, New Zealand, and Greenland, temperatures fell, although with many ups and downs, after 1300 to around 1800 or 1850 A.D., when they began to rebound. There was a cold period in the first decade of the 14th century, another around 1430 and yet again in 1560. The end of that period of increasingly harsh temperatures could have been as early as 1700, 1850, or even as late as 1900 A.D. for Tasmania. The worst period for most of the world occurred between 1550 and 1700 (Lamb 1977, 463). One reasonable interpretation of the data is that the world has been cooling since

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around 4500 B.C. with a temporary upswing during the High Middle Ages.

Europe and Asia cooled substantially from around 1300 to 1850, especially after 1400, with temperatures falling some 2° to 4°F below those of the 20th century. That indicates that temperatures may have dipped by as much as 9°F in the 200 years from 1200 to 1400, a drop of about the same magnitude as the maximum rise forecast from a doubling of CO<sub>2</sub>. Those frigid times did bring hardships; and, as Figure 2-1 shows, world population growth slowed. For much of those centuries, famine and disease stalked Europe and Asia.

Glaciers in North America and northern Europe peaked between the late 1600s and 1730 to 1780. In the Alps the ice sheets reached their maximum between 1600 and 1650 A.D. The cold came later below the equator where the glaciers reached their extreme between 1820 and 1850 (Lamb 1988, 166).

Oxygen isotope ratios from oak trees in Germany document a steady decline in average temperatures from 1350 to about 1800, with the exception of a few small upsurges and one strong temperature spike in the first half of the 18th century (Lamb 1977, 450, fig. 17-12). They also confirm a recovery beginning late in the 19th century to much higher levels. Icelandic records of sea ice attest to an increase between 1200 and the middle of the 14th century and then, starting in the latter half of the 16th century, a marked upswing in ice that appears to have peaked around 1800 (Lamb 1977, 452, fig. 17-13). As H. H. Lamb (1977, 461–62) points out, “In most parts of the world the extent of snow and ice on land and sea seems to have attained a maximum as great as, or in most cases greater than, at any time since the last major Ice Age.”

The Mini Ice Age, especially the century and a half between 1550 and 1700—the exact timing varied around the globe—produced low temperatures throughout the year and considerable variation in weather from year to year and from decade to decade. It included some years that were exceptionally warm (Lamb 1977, 465–66). The polar cap expanded, as did the circumpolar vortex, driving storms and the weather to lower latitudes. Although much of Europe experienced greater wetness than during the earlier warm epoch, it was more the product of less evaporation due to the cold than of excessive precipitation.

The cooling after the High Middle Ages can be seen in the lowering of tree lines in the mountains of Europe, changes in oxygen isotope

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measurement, and advances of the glaciers and of sea ice. That cooling diminished the abundance and quality of wine production in France, Germany, and Luxembourg as depicted in historical documents, such as weather diaries and farm records (Lamb 1977, 246). The ocean, which had reached relatively high levels both in the late Roman period and again during the High Middle Ages, fell to lower elevations in the 17th and 19th centuries (Lamb 1977, 432). As a result of an expanded ice cap, the circumpolar vortex, which funnels weather around the globe, moved south and spawned increasingly cold and stormy weather in middle latitudes. With the exception of the southern United States and central Asia, both of which enjoyed more rainfall, this brought a worsening of the climate and disasters to people almost everywhere. During the coldest period of the 17th century, snow fell above 10,000 feet in the high mountains of Ethiopia that today never see snow. The subtropical monsoon rains decreased and receded farther south, causing droughts in East Asia and parts of Africa (Fairbridge 1984, 181–90).

The expansion of the circumpolar vortex produced some of the greatest windstorms ever recorded in Europe and, not so incidentally, changed history. A terrible tempest destroyed the Spanish Armada in 1588. Fierce gales wracked Europe in December 1703 and on Christmas Day 1717 (Lamb 1988, 158). The contrast between the cold northern temperatures that moved south and the warm subtropical Atlantic undoubtedly generated a fierce jet stream. Although we lack any information, that may also have enhanced tornado activity on the plains of the United States (Lamb 1977, 467).

The reduced temperatures had the following general effects: Arctic sea ice expanded in the Atlantic, eventually cutting off Greenland; glaciers advanced in Iceland, Norway, Greenland, and the Alps; the upper tree line in North America and central Europe lowered; enhanced wetness spawned bogs, marshes, lakes, and floods; rivers and lakes froze more frequently; the number and strength of storms, some of which were extraordinarily destructive, intensified sharply; harvests failed, engendering famine and higher prices for basic foods; peasants abandoned farms that no longer enjoyed reliable weather; and disease for both animals and humans spread (Lamb 1977, 451–52).

As early as 1250, floating ice from the East Greenland ice cap was hindering navigation between Iceland and Greenland (Lamb 1988,

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159). Over the next century and a half, the prevalence of icebergs became worse. By 1410 sea travel between the two outposts of Scandinavia ceased. Based on the ratio of isotopes of oxygen in the teeth of ancient Norsemen, researchers have estimated that the climate in Greenland cooled by about 3°F between 1100 and 1450 (Monastersky 1994, 310). For about 350 years, from the third quarter of the 15th century to 1822, no ships found their way to Greenland and the local population perished (Lamb 1988, 159).

Harvest failures in the last quarter of the 13th century heralded the deteriorating climate in Europe. Compounding the insufficiency was a shift of land from farming—which, because of the change in climate, was more chancy—to enclosure and sheep rearing (Lamb 1977, 7). Average yields, already low by modern standards, worsened after the middle of the 13th century (Donkin 1973, 91). One of the first severe bouts of cold wet weather afflicted Europe from 1310 to 1319, leading to large-scale crop failures (Lamb 1977, 454). Food supplies deteriorated sharply, generating famine for much of Europe in 1315–18 and again in 1321 (Donkin 1973, 90). Harvest deficits and hunger preceded the Black Death by 40 years (Lamb 1977, 266). According to Lamb (1977, 7), in much of the Continent, “the poor were reduced to eating dogs, cats and even children.” That scanty food output contributed to a decline in population that was aggravated by disease. The history of many villages shows that they were abandoned before, not after, the beginning of the plague. By 1327, the population in parts of England—especially those later devastated by the plague—had fallen by 67 percent (Lamb 1977, 454). People poorly nourished were quickly carried off by disease. Between 1693 and 1700 in Scotland, seven of the eight harvests failed and a larger percentage of the population starved than had died in the Black Death of 1348–50 (Lamb 1977, 471).

In two terrible years, 1347 and 1348, famine struck northern Italy, followed by the Black Death, which decimated most of those not already carried away by lack of food (Langer 1968, 317). Bubonic plague spread across the Alps after 1348, killing in the next two years about one-third of northern Europe’s people. Life expectancy fell by 10 years in a little over a century, from 48 years in 1280 to 38 years in the years 1376 to 1400 (Lamb 1982, 189). Crops often failed; peasants abandoned many lands that had been cultivated during the earlier warm epoch. Between 1300 and 1600, the growing

season shrank by three to five weeks with a catastrophic impact on farming (Lamb 1988, 32). In Norway and Scotland, the population declined and villagers deserted many locales well before the plague reached those areas (Lamb 1988, 36). The capitals of both Scotland and Norway moved south before both areas lost their autonomy.

The cooling after 1300 probably contributed significantly to the virulence of the bubonic plague, the greatest disaster ever to befall Europe. The disease appears to have originated around 1333 in China, shortly after major rains and floods in 1332, which are reputed to have caused 7 million deaths while disturbing wildlife and displacing plague-carrying rats (Lamb 1977, 456). Around 1338–39, the Black Death spread to central Asia, which, with the increased coldness, was also drying out. By 1348 rodents carrying fleas infested with bubonic plague had marched or been carried from the Crimea into Europe. Historians have estimated that as many as one-third of all the people in Europe died in the raging epidemic that swept the Continent (Lamb 1977, 262). That outburst of the plague, like a similar one in the 6th century, occurred during a period of increasing coolness, storminess, and wet periods, followed by dry, hot ones. The unpleasant weather is likely to have confined people to their homes where they were more likely to be exposed to the fleas that carried the disease. In addition, the inclement weather may have induced rats to take shelter in buildings, exposing their inhabitants to the bacillus.

Not only did the cold facilitate the spread of the plague, but it caused much other human suffering. Several centuries later, in July 1789, just before the French Revolution, wet weather and air temperatures between 59 and 85°F produced an ergot blight in the rye crop of Brittany and other parts of France. The blight induced hallucinations, paralysis, abortions, and convulsions and came after a very cold winter that had created severe food shortages (Lamb 1988, 165). Earlier in that century wet, cold summers had brought about two years of famine in Europe.

The end of the medieval warmth had devastating effects on populations that lived at the edge of habitable lands. Historians, for example, have estimated the population of Iceland in the last decades of the 11th century at about 77,000; and early in the 14th it still numbered over 72,000. By 1800, after several hundred years of coolness and stormy weather, the poor conditions had more than halved,

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to 38,000, the number of Icelanders (Lamb 1977, 265; from Thorarinson 1961).

The terrible climate in Europe after the 13th century brought a halt to the economic boom of the High Middle Ages. Innovation slowed sharply (Gimpel 1983, 150). Except for military advances, technological improvements ceased for the next 150 years. Population growth not only ended but, with starvation and the Black Death, fell. Without the drive of additional numbers of people, colonial enterprise ceased and no new lands were reclaimed nor towns founded. The economic slump of 1337 brought on the collapse of the great Italian bank, Scali, leading to one of the first recorded major financial crises (Gimpel 1983, 151). Construction halted on churches and cathedrals.

The hardships of the 14th century induced a search for scapegoats. In 1290, after some years of crop failures, the king of England expelled the entire Jewish population from the country. The French king followed that example in 1306 and again in 1393 (Pirenne c. 1938, 134). In 1349, the Christians of Brabant massacred local Jews; they expelled the remainder 21 years later.

The Mini Ice Age at its coldest devastated the fishing industry. From 1570 to 1640, during the most severe period, Icelandic documents record an exceptionally high number of weeks with coastal sea ice. Between 1615 and 1828, with the exception of a few years, fishermen from the Faeroe Islands suffered from a lack of cod—cod needs water warmer than 36°F to flourish. During the worst period, 1685 to 1704, fishing off southwest Iceland failed totally (Lamb 1988, 153–54, 155). In the very icy year of 1695, Norwegian fishermen found no cod off their coast. Lamb calculates that the sea around the Faeroe Islands was probably 7° to 9°F colder than it had been over the last century (1988, 156, 160).

The Mini Ice Age brought hard times to southern Europe as well. Severe winters and wet summers created shortages and famines in the south of France and in Spain. The great variability in the weather made agricultural output uncertain and contributed to a farming crisis in the Iberian Peninsula. Although there were certainly other causes as well, it seems very likely that the deterioration in climate contributed greatly to the economic decline of the Mediterranean littoral in the 17th century (Lamb 1977, 469).

The cold had devastating effects elsewhere in the world. Between 1646 and 1676, frosts killed the orange trees in the Chinese province

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of Kiangsi (Lamb 1977, 471). As food prices rose, per capita incomes fell. As already mentioned, cooler weather brought an end to the Anasazi Indian pueblo culture and to native American farming in the upper Midwest.

According to Nicolas Cheetham, in the second half of the 13th century, warfare in Greece and the necessity of keeping a large military establishment under arms reduced the country's previous prosperity. War does exact a high toll on economies, but it seems extraordinarily coincidental that economic troubles occurred at the time Europe was experiencing a deteriorating climate. In 1268, the king of Naples, in gratitude for military service, sent wheat, barley, and cattle to the Peloponnese to relieve the hunger caused by crop failures (Cheetham 1981, 98–99). Were the crop failures caused solely by military disruptions? Although his death was not necessarily weather related, in 1275 Geoffroy de Briel, a major figure in medieval Greece, died during a military campaign of dysentery, a disease often exacerbated by cold, wet conditions (Cheetham 1981, 101).

Notwithstanding the cooling climate and the ravages of disease after 1300, European civilization recovered in the 15th century with the advent of the Renaissance. This burst of cultural activity represented a continuation, an expansion, and a deepening of the artistic and intellectual activity of the High Middle Ages. Ironically, the plague may have established the conditions necessary for the outpouring of art, science, and literature that made up the Renaissance. The colder climate made agriculture more chancy, reduced the territory available for farming, and cut yields. Yet without the one-third drop in Europe's population caused by the Black Death, food supplies would have been too meager to support a large artistic and cultured class that promoted and supported the arts. The reduced agricultural output, however, was still large enough to support the even more diminished population. In China, which experienced a slower decline in numbers, real wages fell and the people became increasingly impoverished (Kremer 1993, 714, app. A; Chao 1986, 218, table 9-2). But in Europe, as a result of such a terrible death rate over a short period, real incomes for the survivors actually climbed (Rosenberg and Birdzell Jr. 1986, 54).

From roughly 1550 to 1700, the globe suffered from the coldest temperatures since the last Ice Age. Lamb estimates that in the 1590s and 1690s the average temperature was 3°F below the present. Grain

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prices increased sharply as crops failed. Famines were common. The Renaissance had ended; Europe was in turmoil. The Continent suffered from cold and rain, which produced poor growing conditions, food shortages, famines, and finally riots in the years 1527–29, 1590–97, and the 1640s. The shortages between 1690 and 1700 killed millions; they were followed by more famines in 1725 and 1816 (Ladurie 1971, 64–79).

China, Japan, and the Indian subcontinent were also afflicted with severe winters between 1500 and 1850–80. Despite the development of a new type of rice that permitted the cultivation of three crops a year on the same land—up from two—the population of China, as well as that of Korea and the Near East, declined for two centuries after 1200, undoubtedly reflecting a deteriorating climate (Carruth 1993, 166, 168).

### **Happiness Is a Warm Planet**

History has shown us that warm periods are significantly better than cold periods. During the best of times, human populations have gone up rapidly, new techniques and practices have developed, and building and art have flourished. The record shows that human beings spent hundreds of thousands of years as hunter-gatherers, living like many other mammals. Only when the weather warmed did our ancestors domesticate plants and animals and cease scavenging from the land and begin to shape the environment. During the Climatic Optimum of 3,000 to 8,000 years ago, people built the first cities and established city states and then empires. During that period, trade flourished, writing was invented, and the human population exploded. The warmer weather was accompanied by more plentiful rainfall, especially in North Africa and Arabia. Hardwood forests flourished throughout northern Europe.

The climate turned somewhat cooler about 1000 B.C. but was interspersed with some periods of warmth until around 600 A.D. For the next 300 years, the weather was cold and damp, not because of rainfall but from lack of evaporation. In Europe, progress, civilization, and trade came to a standstill.

From 900 to 1300 A.D., especially after the start of the new millennium, warm, sunny weather returned and the population exploded. Traders developed great fairs throughout Europe. Lured by better

## CLIMATE OF FEAR

weather, people colonized new regions, especially at higher elevations and farther north. The Norsemen occupied Iceland and Greenland and apparently explored the northern reaches of North America. Europeans went on a building spree reflecting the new affluence and the plentiful supply of labor.

Asians also flourished during this Little Climatic Optimum, building large temples, setting up trading systems, creating great art and literature, and inventing new agricultural implements. In North America, the Anasazi Indians built their pueblos while other native Americans farmed what is now western Wisconsin and eastern Minnesota.

With the onslaught of colder weather at the end of the 13th century, the good times of the High Middle Ages came to an abrupt halt. Except during a few periods of clement weather, famine, plague, and warfare were to torment mankind for the next few centuries.

As noted, not all regions or all peoples benefited from a shift to a warmer climate in the past and the same is true of the present and future. Some locales may become too dry or too wet; others may become too warm. Certain areas may be subject to high pressure systems that block storms and rains. Others may experience the reverse. On the whole, though, mankind has benefited and will continue to benefit from an upward tick in the thermometer. Warmer weather means longer growing seasons, more rainfall overall, and fewer and less violent storms.

History teaches us that warmer is better, colder is worse. The optimal way to deal with potential climate change is not to strive to prevent it (a useless activity in any case, as we shall see) but to promote growth and prosperity so that people will have the resources to deal with any shift, whether toward a warmer or a colder climate.