CHAPTER 1

Humankind Emerges: Tools and Toolmakers

Scholars customarily draw a sharp distinction between *prehistory* and *history.* Prehistory is taken to be the long era from the biological beginnings of humankind over 2 million years ago to the origins of civilization about 5,000 years ago in the first urban centers of the Near East. The transition to civilization and the advent of written records traditionally mark the commencement of history proper.

Prehistory, because of the exclusively material nature of its artifacts, mainly in the form of stone, bone, or ceramic products, has inescapably become the province of the archaeologist, while the historical era, with its documentary records, is the domain of the historian. However, the single label "prehistory" obscures two distinctly different substages: the *Paleolithic,* or Old Stone Age, which held sway for around 2 million years, is marked by rudimentary stone tools designed for collecting and processing wild food sources, while the succeeding *Neolithic,* or New Stone Age, which first took hold in the Near East around 12,000 years ago, entailed substantially more complex stone implements adapted to the requirements of an economy of low-intensity food production in the form of gardening or herding.

The technologies of both the Paleolithic and Neolithic eras have left a rich legacy of material artifacts. In contrast, only a feeble record exists of any scientific interests in these preliterate societies, mainly in the form of astronomically oriented structures. Thus, at the very outset, the evidence indicates that science and technology followed separate trajectories during 2,000 millennia of prehistory. Technology—the crafts—formed an essential element of both the nomadic food-collecting economy of Paleolithic societies and the food-producing activities in Neolithic villages, while science, as an abstract and systematic interest in nature, was essentially nonexistent, or, at any rate, has left little trace.

The Arrival of Handyman

By most accounts human beings appeared on Earth only recently, as measured on the scales of cosmic, geologic, or evolutionary time. As scientists now believe, the cosmos itself originated with the "Big Bang" some 12 to 15 billion years ago. Around 4 billion years ago the earth took shape as the third in a string of companion planets to an ordinary star near the edge of an ordinary galaxy; soon the self-replicating chemistry of life began. Biological evolution then unfolded over the next millions and billions of years. In the popular imagination the age of the dinosaurs exemplifies the fantastic history of life in past ages, and the catastrophic event—probably a comet or an asteroid colliding with the earth—that ended the dinosaur age 65 million years ago illustrates the vicissitudes life suffered in its tortuous evolution. The period that followed is known as the age of mammals because these animals flourished and diversified in the niche vacated by the dinosaurian reptiles. By about 4 million years ago a line of "ape-men" arose in Africa—the australopithecines—our now-extinct ancestral stock.

Figure 1.1 depicts the several sorts of human and prehuman species that have arisen over the last 4 million years. Experts debate the precise evolutionary paths that join them, and each new fossil discovery readjusts the details of the story; yet its broad outlines are not in dispute.

The figure shows that anatomically modern humans, *Homo sapiens sapiens,* or the "wise" variety of "wise Man," evolved from a series of human and prehuman ancestors. Archaic versions of modern humans made their appearance after about 500,000 years ago, with the Neanderthals being an extinct race of humans that existed mainly in the cold of Europe between 135,000 and 35,000 years ago. Scholars differ over the modernity of Neanderthals and whether one would or would not stand out in a crowd or in a supermarket. Many scientists look upon them as so similar to ourselves as to form only an extinct variety or race of our own species, and so label them *Homo sapiens neanderthalensis.* Others think Neanderthals more "brutish" than anatomically modern humans and therefore regard them as a separate species, *Homo neanderthalensis.*

Preceding *Homo sapiens,* the highly successful species known as *Homo erectus* arose around 2 million years ago and spread throughout the Old World (the continents of Africa, Europe, and Asia). Before that, the first species of human being, *Homo habilis,* coexisted with at least two other species of upright hominids, the robust and the gracile forms of the species *Paranthropus.* At the beginning of the sequence stood the ancestral genus *Australopithecus* (or "Southern Ape") that includes *Australopithecus afarensis*—represented by the fossil "Lucy."

This sequence highlights several points of note. First is the fact of human evolution, that we arose from more primitive forebears. Among the more significant indicators of this evolution is a progression in brain

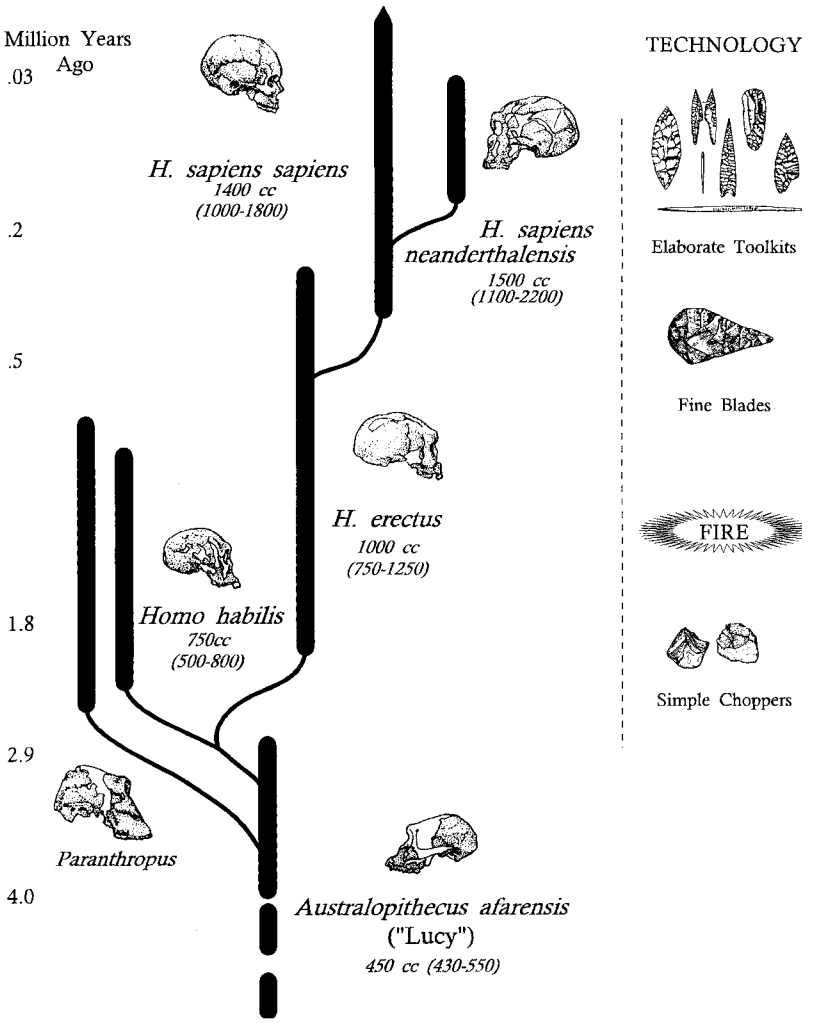

Fig. 1.1. Human evolution. Modern humans (*Homo sapiens sapiens*) evolved from earlier, now extinct, human and prehuman ancestors. (Plants and animals are classified according to the binomial nomenclature of genus and species: genus being general groups of related species, and species being specific interbreeding populations of individuals. Thus, *Homo* is the genus, and *sapiens* the species; the third name indicates a subspecies.) In general, brain size and technological sophistication increased over time, but there is no strict correlation between species and technologies. For example, *Paranthropus* and *Homo habilis* may both have used simple choppers; *H. erectus* and archaic *H. sapiens* cannot be distinguished by their respective fine-blade tool kits. Aspects of this picture are matters of debate, notably the relationship of Neanderthals to modern humans. New findings regularly shed new light on the details of human biological and cultural evolution.

size, from around 450 cubic centimeters (cc) in the case of prehuman Lucy, only slightly larger than the brain of a modern chimpanzee, through an average of 750 cc for *Homo habilis,* 1000 cc for *Homo erectus,* to around 1400 cc for humanity today. An as-yet-unexplained irony of this "progression" is that Neanderthals had slightly larger brains than today's humans.

Bipedality—or walking upright on two feet—represents another defining feature of this evolutionary sequence. Experts debate whether Lucy and her kin were fully bipedal, but her successors certainly were. An upright stance allows the hand and arm to become a multipurpose utensil for grasping and carrying items. Lucy and her type had probably adopted male-female cooperation, at least temporary pair-bonding, and a "family" structure for raising offspring.

From the point of view of the history of technology, however, the most important lesson to be drawn from figure 1.1 concerns tool use among our ancestors. It used to be thought that tool use—technology—

is an exclusively human characteristic; the oldest fossil of the human genus, *Homo habilis,* received its name ("handy man") both because of its "human" skeletal features and because it was discovered along with simple stone choppers. However, the older notion can no longer be maintained. Indeed, the origin of technology is rooted in biology. Some nonhuman animals create and use tools, and technology as a cultural process transmitted from generation to generation arises occasionally among monkey and ape communities. Chimpanzees in the wild sometimes "fish" for termites by carefully preparing a twig, inserting it into a termite nest, and licking off the insects that cling to it. Since the activity is not instinctive but is instead taught to juveniles by their mothers, it must be regarded as cultural, unlike, say, the instinct of bees to build hives. Reportedly, chimpanzees have also culturally transmitted knowledge of medicinal plants, so it may be possible to identify the origins of medical technology outside of the human genus, too. Perhaps the best documented feats of technical innovation and cultural transmission in the animal world concern a single female, Imo, the "monkey genius" of a colony of Japanese macaques. Incredibly, Imo made two separate technical discoveries. First she discovered that to remove sand from potatoes thrown on the beach she could wash them in the sea rather than pick off the sand with her fingers. Then, in an even more remarkable display of ingenuity, Imo found that to separate *rice* from sand she did not have to pick out the individual grains; the mixture can be dropped into water where the sand will sink, and the rice will float and can be easily recovered. Both techniques were adopted by younger members of the troop as well as by older females and passed on to the next generation.

Claims have been made that not only *Homo habilis* but also species of *Paranthropus* probably made stone implements and may have used fire. Furthermore, little correlation exists between species type and different types of toolkits. For example, Neanderthal tools varied little from the precedents set by *Homo erectus*. The record reveals only a weak correlation between biological species and the toolkit used.

That said, however, making and using tools and the cultural transmission of technology became essential to the human mode of existence and was practiced in all human societies. Moreover, humans seem to be the only creatures who fashion tools to make other tools. Without tools humans are a fairly frail species, and no human society has ever survived without technology. Humankind owes its evolutionary success in large measure to mastery and transmission of toolmaking and -using, and thus human evolutionary history is grounded in the history of technology.

Control of fire represented a key new technology for humankind. Fire provided warmth. Fire made human migration into colder climes possible, opening up huge and otherwise inhospitable areas of the globe for human habitation. The technology of fire also supplied arti-

ficial light, thus extending human activity after dark and into dark places, such as caves. Fire offered protection against wild animals. Fire permitted foods to be cooked, which lessened the time and effort required to eat and digest meals. Fire-hardened wooden tools became possible. And fire no doubt served as a hearth and a hub for human social and cultural relations for a million years. Their practical knowledge of fire gave early humans a greater degree of control over nature. *Homo erectus* was an exceptionally successful animal, at least as measured by its spread across the Old World from Africa to Europe, Asia, Southeast Asia, and archipelagoes beyond. That success in large measure depended on mastering fire.

The grasping hand constitutes one human "tool" that evolved through natural selection; speech is another. Speech seems to be a relatively recent acquisition, although paleontologists have not yet reached agreement on how or when it first appeared. Speech may have evolved from animal songs or calls; novel brain wiring may have been involved. But, once acquired, the ability to convey information and communicate in words and sentences must have been an empowering technology that produced dramatic social and cultural consequences for humanity.

A turning point occurred around 40,000 years ago. Previously, Neanderthals and anatomically modern humans had coexisted for tens of thousands of years in the Middle East and in Europe. Around 35,000 years ago Neanderthals became extinct, possibly exterminated through conflict with a new population, or they may have interbred and become absorbed into the modern human gene pool. A cultural discontinuity manifested itself around the same time. Whereas Neanderthals had produced simple, generalized, multipurpose tools from local materials, we—*Homo sapiens sapiens*—began to produce a great assortment of tools, many of which were specialized, from stone, bone, and antler: needles and sewn clothing, rope and nets, lamps, musical instruments, barbed weapons, bows and arrows, fish hooks, spear throwers, and more elaborate houses and shelters with fireplaces. Humans began to conduct long-distance trade of shells and flints through exchange over hundreds of miles, and they produced art, tracked the moon, and buried their dead. And yet, in terms of their basic social and economic way of life, they continued along the same path—they remained nomadic food-collectors.

Foraging for a Living

Prehistorians classify the period from 2 million years ago to the end of the last Ice Age at about 12,000 years ago as a single era. They label it the Paleolithic (from the Greek, *paleo,* "ancient"; *lithos,* "stone") or Old Stone Age. Food-collecting is its essential attribute, codified in the term *hunter-gatherer* society. Paleolithic tools aided in hunting or scavenging animals and for collecting and processing plant and animal food,

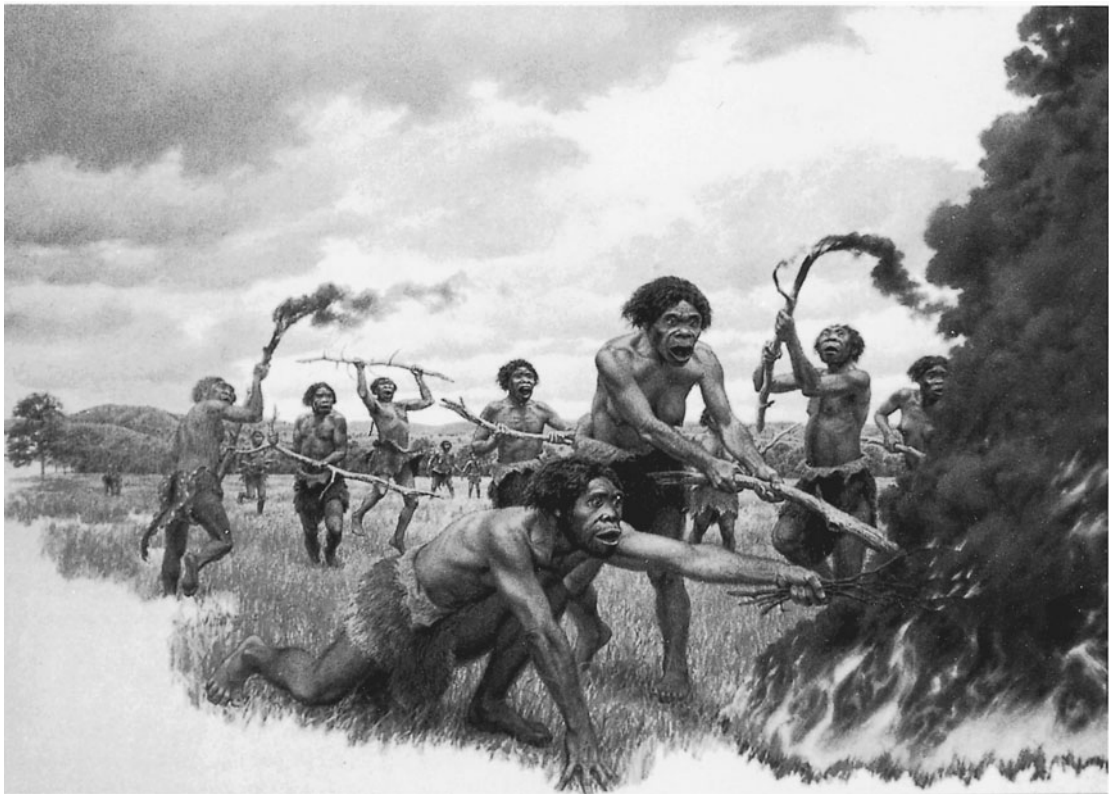

Fig. 1.2. "*H. erectus* Utilizing a Prairie Fire," by Jay H. Matternes. Control of fire became a fundamental technology in the human odyssey. Undoubtedly, members of the genus *Homo* first used wildfires before learning to control them.

and it is now understood that Paleolithic technology developed in the service of a basic food-collecting economy.

Paleolithic food-collecting bespeaks a subsistence economy and a communal society. Seasonal and migratory food-collecting produced little surplus and thus permitted little social ranking or dominance and no coercive institutions (or, indeed, any institutions) of the kind needed in stratified societies to store, tax, and redistribute surplus food. The record indicates that Paleolithic societies were essentially egalitarian, although grades of power and status may have existed within groups. People lived in small bands or groups of families, generally numbering fewer than 100. Much circumstantial evidence suggests that a division of labor based on gender governed the pattern of food collection. Although one has to allow for sexually ambiguous roles and individual exceptions, males generally attended to hunting and scavenging animals, while females most likely went about gleaning plants, seeds, and eggs as food and medicines. Men and women together contributed to the survival of the group, with women's work often providing the majority of calories. *Homo sapiens sapiens* lived longer than Neanderthals, it would seem; more true elders thus added experience and knowledge in those groups. Paleolithic bands may have converged seasonally into larger clans or macrobands for celebrations, acquiring mates, or other collective activities, and they probably ingested hallu-

cinatory plants. Except as located in a handful of favored spots where year-round hunting or fishing might have been possible, Paleolithic food-collectors were nomadic, following the migrations of animals and the seasonal growth of plants. In some instances Paleolithic groups engaged in great seasonal moves to the sea or mountains. In the Upper Paleolithic (around 30,000 years ago) spear-throwers and the bow and arrow entered the weapons arsenal, and the dog (wolf) became domesticated, possibly as an aid in hunting.

Ice Age art is the most heralded example of the cultural flowering produced after anatomically modern humans appeared on the scene. Earlier human groups may have made beautified objects of perishable materials, but several late Upper Paleolithic cultures in Europe (30,000 to 10,000 years ago) produced enduring and justly renowned paintings and sculptures in hundreds of sites, often in hard-to-reach galleries and recesses of caves. Artists and artisans also created jewelry and portable adornments, and decorated small objects with animal motifs and other embellishments. No one has yet fully decoded what purposes cave paintings fulfilled; anthropologists have suggested hunting rituals, initiations, magical beliefs, and sexual symbolism. The many "Venus" statuettes with exaggerated feminine features, characteristic of the Paleolithic, have been interpreted in terms of fertility rituals and divination of one sort or another. By the same token, they may represent ideals of feminine beauty. But we should not overlook the technical dimension of Ice Age art, from pigments and painting techniques to ladders and scaffolding. The great cave paintings of Europe are the better known, but literally and figuratively Paleolithic peoples the world over left their artistic handprints.

Neanderthals had already begun to care for their old and invalid, and by 100,000 years ago they ceremonially buried some of their dead. Centers of mortuary and burial activity may have existed, and one can speak of a "cult of the dead" beginning in the Middle Paleolithic (100,000–50,000 years ago). Intentionally burying the dead is a distinctly human activity, and burials represent a major cultural landmark in human prehistory. They bespeak self-consciousness and effective social and group cohesion, and they suggest the beginning of symbolic thought.

It may be enlightening to speculate about the mental or spiritual world of Paleolithic peoples. What we have already seen and said of Paleolithic burials and cave art strongly suggests that Paleolithic populations, at least toward the end of the era, developed what we would call religious or spiritual attitudes. They may well have believed the natural world was filled with various gods or deities or that objects and places, such as stones or groves, were themselves alive. Religious beliefs and practices—however we might conceive them—formed a social technology, as it were, that knitted communities together and strengthened their effectiveness.

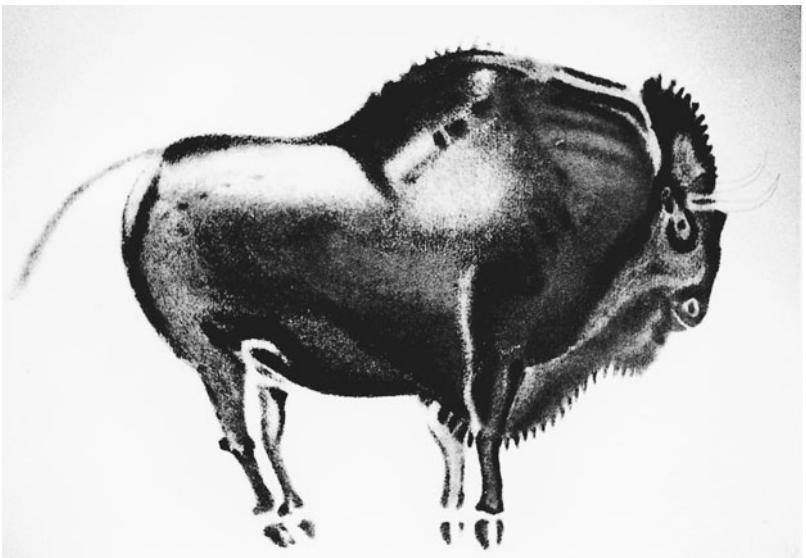

Fig. 1.3. Paleolithic art. In the late Paleolithic era food-collecting populations of *Homo sapiens* began to create art in many parts of the world. In southwestern Europe they adorned the walls of caves with naturalistic representations of animals.

For anatomically modern humans the Paleolithic way of life continued unabated and essentially unchanged for 30,000 years, a phenomenally long and stable cultural era, especially compared to the rapid pace of change in the periods that followed. Paleolithic peoples doubtless lived relatively unchanging lives involving great continuity with their own past. Well fed on a varied diet that included significant amounts of meat, not having to work too hard, cozy in fur and hide, comfortable by a warm fire, who can deny that our Paleolithic ancestors often enjoyed the good life?

Over the entire 2 million years of the Paleolithic, beginning with the first species of *Homo,* population density remained astonishingly low, perhaps no more than one person per square mile, and the rate of population increase, even in the late (or Upper) Paleolithic, may have been only one-five-hundredth of what it has been for modern populations over the past few centuries. The very low rate of population increase derives from several factors acting singly or in combination to restrict fertility rates: late weaning of infants (since nursing has somewhat of a contraceptive effect), low body fat, a mobile lifestyle, and infanticide. Nevertheless, humankind slowly but surely fanned out over the earth and, as long as suitable food-collecting habitats could be found, humanity had no need to alter its basic lifestyle. Food-collecting groups simply budded off from parent populations and founded new communities. Paleolithic peoples spread through Africa, Asia, Europe, and Australia, while waves of hunters and gatherers reached North America by at least 12,000 years ago, if not well before, ultimately spreading the Paleolithic mode of existence to the southernmost tip of South America. After many millennia of slow expansion, Paleolithic humans "filled up" the world with food-collectors. Only then, it seems, did population pressure against collectible resources trigger a revolutionary

change from food-collecting to food-producing in the form of horticulture or herding.

Is Knowledge Science?

The extraordinary endurance of Paleolithic society and mode of existence depended on human mastery of an interlocked set of technologies and practices. It is sometimes said that Paleolithic peoples needed and possessed "science" as a source of the knowledge that underpinned their practical activities. It is all too easy to assume that in making and using fire, for example, Stone Age peoples practiced at least a rude form of "chemistry." In fact, however, while both science and technology involve "knowledge systems," the knowledge possessed by food-collectors cannot reasonably be considered theoretical or derivative of science or theories of nature. Although evidence of something akin to science appears in late Paleolithic "astronomy," it evidently played no role in the practice of Paleolithic crafts. To discover the origins and character of that science we need to understand why it did not impact technology.

Practical knowledge embodied in the crafts is different from knowledge deriving from some abstract understanding of a phenomenon. To change a car tire, one needs direct instruction or hands-on experience, not any special knowledge of mechanics or the strength of materials. By rubbing sticks together or sparking flint into dry kindling, a scout can build a fire without knowing the oxygen theory (or any other theory) of combustion. And conversely, knowledge of theory alone does not enable one to make a fire. It seems fair to say that Paleolithic peoples applied practical skills rather than any theoretical or scientific knowledge to practice their crafts. More than that, Paleolithic peoples may have had explanations for fire without it being meaningful to speak about Paleolithic "chemistry"—for example, if they somehow thought they were invoking a fire god or a spirit of fire in their actions. A major conclusion about Paleolithic technology follows from all this: to whatever small extent we may be able to speak about "science" in the Paleolithic, Paleolithic technologies clearly were prior to and independent of any such knowledge.

The record (or rather the absence of one) indicates that Paleolithic peoples did not self-consciously pursue "science" or deliberate inquiries into nature. Does the Paleolithic period nevertheless offer anything of note for the history of science? On the most rudimentary level one can recognize the extensive "knowledge of nature" possessed by Paleolithic peoples and gained directly from experience. They had to be keen observers since their very existence depended on what they knew of the plant and animal worlds around them. And, like surviving food-collectors observed by anthropologists, they may have developed taxonomies and natural histories to categorize and comprehend their observations.

Even more noteworthy, the archaeological record for the late Pale-

olithic era, beginning around 40,000 years ago, offers striking evidence of activities that look a lot like science. That evidence appears in the form of thousands of engraved fragments of reindeer and mammoth bones that seem to have recorded observations of the moon. An "unbroken line" of such artifacts stretches over tens of thousands of years. The engraved mammoth tusk from Gontzi in Ukraine is an example of such lunar records, which may have been kept at all major habitation sites. Pictured in figure 1.4, it dates from around 15,000 years ago.

We can only speculate, of course, but, as Paleolithic peoples lived close to nature, the waxing and waning moon would naturally present itself as a significant object of interest with its obvious rhythms and periods. One can easily imagine our intelligent forebears following those rhythms and beginning to record in one fashion or another the sequence and intervals of full and new moon. Moreover, the Gontzi bone and others like it could have served as a means of reckoning time. Although we cannot go so far as to say that Paleolithic peoples possessed a calendar, we can surmise that knowledge of the moon's periods would be useful in time-reckoning. For example, dispersed groups might have come together seasonally and would have needed to keep track of the intervening months. We need not envision a continuous tradition of such lunar records, for the process may have been invented and reinvented hundreds of times over: a simple counter fashioned over the course of a few months and discarded. The artifacts in question evidence the active observation and recording of natural phenomena over time. That activity indicates only a rudimentary approach to theoretical knowledge, but its results seem more abstract than knowledge gained from direct experience and different from what Paleolithic peoples otherwise embodied in their crafts.

Leaving the Garden

This picture of humankind's childhood, which has emerged from the research of archaeologists, paleoanthropologists, and prehistorians, raises several puzzling questions about the dynamics of social change. How can we explain the steadfast durability of a food-collecting social system for 2 million years including more than 200,000 years populated by our own species? How can the relative lack of technological innovation be accounted for? Why, after anatomically modern humans flourished culturally in the Paleolithic 40,000 to 30,000 years ago, did they continue to live as food-collectors, making stone tools and following a nomadic way of life? And why did the pace of change accelerate 15,000 years ago, as food-collecting finally gave way to food-producing, first in the form of gardening (horticulture) and animal husbandry in the Neolithic era and later, after another technological revolution in

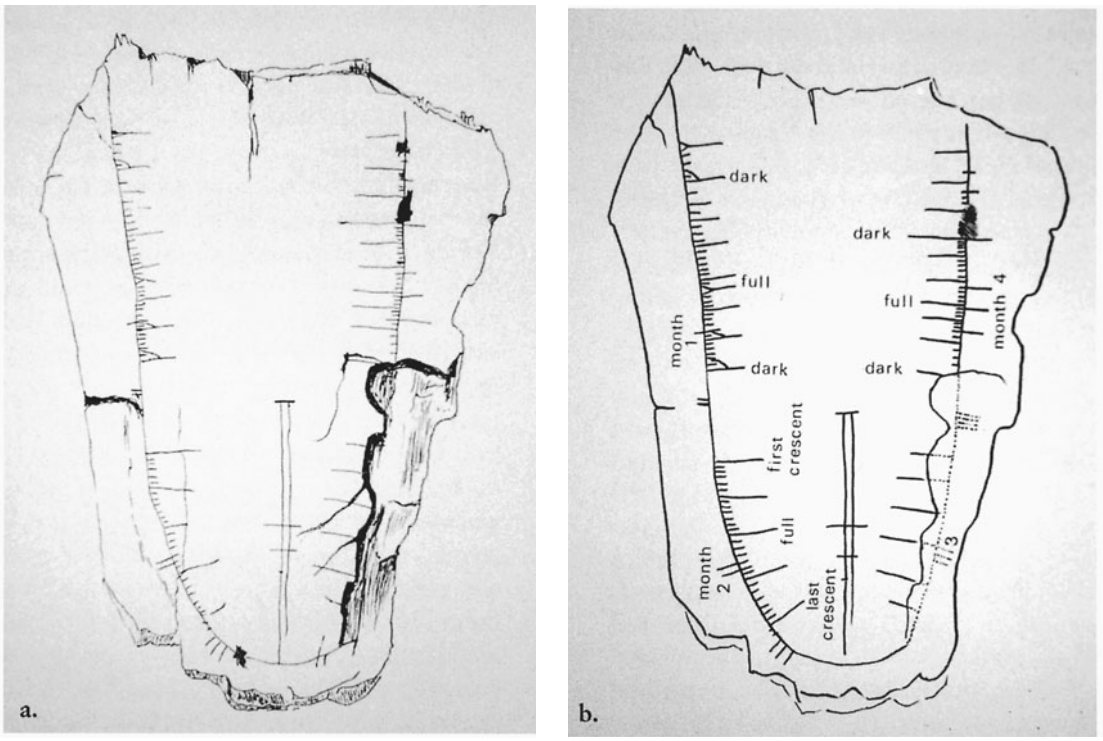

Fig. 1.4. Paleolithic lunar observations. a) An engraved mammoth tusk from Gontzi, Ukraine, that has been interpreted as a record of lunar cycles. Thousands of these artifacts have been found stretching back 30,000 years. This one dates from approximately 15,000 years ago. b) A diagrammatic rendition of the artifact showing cycles of four lunar months aligned with the engraved markings.

the form of intensified farming (agriculture) under the control and management of the political state?

Different explanations have been offered to explain the social and economic transformations that occurred at the end of the Paleolithic. It may have been set in motion by climate change and the retreat of the glaciers at the end of the last Ice Age about 10,000–12,000 years ago. The extinction of many large-bodied animals occurred then, restricting the food supply, and other animal-migration patterns shifted northward, probably leaving some human groups behind. Humans themselves probably overhunted large game, self-destructively changing their living conditions. Another line of argument that has recently gained credibility postulates that the food-collecting mode of life persisted as long as the population of hunters and gatherers remained small enough to exploit the resources of their habitats with reasonable ease. Since population increased slowly and since suitable habitats were numerous on a global scale, 2 million years passed before hunter-gatherers reached the "carrying capacities" of accessible environments through the increase of their own numbers and a resulting broadening of foraging activity. This account also explains the low rate of technological innovation prior to the late Paleolithic era: small populations blessed with ample resources were served well by their techniques and refined skills. Although Paleolithic peoples would have known that seeds grow and that gardening is possible (and occasionally practiced

it), they had no compelling incentive to revolutionize their way of life. Only when increasing population density that could no longer be readily relieved by migration finally upset the balance between needs and resources were plant and animal husbandry taken up as a new way of life.

Our ancestors did not give up their Paleolithic existence willingly. By abandoning, under pressure of ecological degradation, a nomadic lifestyle of food-collecting, and adopting a mode of food-producing—by "progressing" from hunting and gathering to gardening and stock-raising—only then did humankind reluctantly fall out of the Garden of Eden into the Neolithic era.