

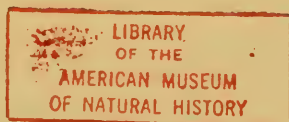
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FIFTY-FOURTH
JAMES ARTHUR LECTURE ON
THE EVOLUTION OF THE HUMAN BRAIN
1984

HIERARCHICAL EVOLUTION OF THE HUMAN CAPACITY: THE PALEOLITHIC EVIDENCE

ALEXANDER MARSHACK

AMERICAN MUSEUM OF NATURAL HISTORY
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JAMES ARTHUR LECTURES ON THE EVOLUTION OF THE HUMAN BRAIN

- Frederick Tilney, *The Brain in Relation to Behavior*; March 15, 1932
- C. Judson Herrick, *Brains as Instruments of Biological Values*; April 6, 1933
- D. M. S. Watson, *The Story of Fossil Brains from Fish to Man*; April 24, 1934
- C. U. Ariens Kappers, *Structural Principles in the Nervous System; The Development of the Forebrain in Animals and Prehistoric Human Races*; April 25, 1935
- Samuel T. Orton, *The Language Area of the Human Brain and Some of Its Disorders*; May 15, 1936
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- *Karl H. Pribram, *What Makes Man Human*; April 23, 1970**
- Walle J. H. Nauta, *A New View of the Evolution of the Cerebral Cortex of Mammals*; May 5, 1971
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- *Leonard Radinsky, *The Fossil Record of Primate Brain Evolution*; March 26, 1979**

Norman Geschwind, *Anatomical Asymmetry of the Brain in Humans and Animals: An Evolutionary Perspective*; April 7, 1980

Irving T. Diamond, *Evolution of the Primate Neocortex*; March 23, 1981

*Robert D. Martin, *Human Brain Evolution in an Ecological Context*; April 27, 1982

Eric Kandel, *Molecular Explorations into Learning and Memory*; April 27, 1983

*Alexander Marshack, *Hierarchical Evolution of the Human Capacity; The Paleolithic Evidence*; May 1, 1984

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HIERARCHICAL EVOLUTION OF THE HUMAN CAPACITY: THE PALEOLITHIC EVIDENCE

It may seem odd that this annual lecture on the evolution of the human brain is being given by a researcher into the art, symbol, and culture of the last European Ice Age rather than a specialist in the structure and function of the living brain. The fact is that two of the pioneers in the study of the structure and function of the brain in the 19th century, the French paleontologist Edouard Lartet, and the French neuroanatomist, Paul Broca, were pioneers in the early study of Ice Age art and the skeletons and skulls of the early Ice Age artists. Their primary interest in that period of unfolding “natural science” was *man*, man as a species and his evolution. This lecture follows along the path of these two pioneers and will touch on their early work.

Edouard Lartet was a French researcher who, for many years before Darwin published *The Origin of Species*, had been excavating fossils of the extinct animals that once roamed Europe. It was he who first proposed that, as one progressed up the ladder of evolution among the mammals, the brain grew progressively larger in relation to body size and that this trend reached its peak among the primates and man. That finding remains one of the crucial axioms in the modern study of the evolution of the brain (Jerison, 1973). With the publication of *The Origin of Species* in 1859, the possibility presented itself that man may have lived in Europe concurrently with the extinct animals that Lartet was finding. A French amateur archaeologist, Boucher de Perthes, had for decades been digging up hand axes associated with the bones of extinct animals but it was not until 1859, the year in which the *Origin* was published, that these tools of prehistoric man were finally validated. Four years after publication of Darwin's book, Lartet began to excavate stone tools, remains of meals, and bones which had been carved and engraved with animal images in the area of the tiny village of Les Eyzies in southwest France. At a small riverside shelter called La Madeleine, a half-hour by foot from the village, Lartet found in 1864 a fragment of mammoth ivory engraved with an extinct woolly mammoth (Fig.

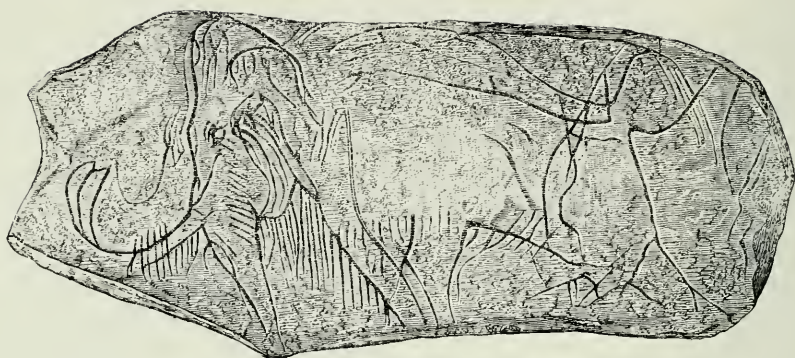


Fig. 1. Engraved mammoth on section of mammoth ivory. La Madeleine, France. Late Magdalenian, c. 11,000 B.C. (after Broca, 1872).

1). That engraving was the first proof that humans capable of making images and art lived in Europe in the time of the mammoth, thousands of years before history began. Lartet spent the rest of his life excavating the sites of early man in the Les Eyzies area. His work with the Englishman, Henry Christy, gave us the first body of Ice Age art, at once raising questions concerning the relevance of this early art and symbol to these prehistoric cultures and the evolution of man. In 1867 and 1868, Lartet was elected secretary of the first two International Congresses of Anthropology, held in London and Paris. He was one of the founders, then, of several disciplines, including modern paleontology and the comparative study of evolution of the brain, Ice Age archaeology and the study of Ice Age art, and of French anthropology, or the study of man in general.

In 1861, shortly before Lartet began excavating at Les Eyzies, his colleague, the neuroanatomist Paul Broca, delivered a paper to the French Society for the Advancement of Science, announcing one of the crucial analytical discoveries in the study of the human brain. Broca had examined the brain of a deceased patient who had previously lost the capacity to talk and he found that the loss of speech had been caused by a lesion in the frontal lobe of the left hemisphere. That finding, concerning what is today known as “Broca’s area,” began the study of localization of brain function, left-hemisphere dominance for language, and left/right hemisphere asymmetry—



a, Tayac Church.

b, Les Eyzies Railway-station.

c, Cro-Magnon Cave.

d, Rock of Les Eyzies.

e, Château of Les Eyzies.

f, Railway-bridge across the Vézère.

Fig. 2. The village of Les Eyzies at the foot of the limestone cliff, with the railroad bridge that was being built when the Cro-Magnon skeletons were found (after L. Lartet, 1875).

studies that are still the bedrock of inquiries into higher brain function. Broca had also begun the histological analysis of brain tissue, one of the major techniques for research in comparative brain differences and the localization of specialized function. At the end of his life he made another major discovery, this time not about a function of the higher cortex, but about a portion of the lower sub-cortex. He located and named the system found just below the cerebral cortex in all animals, including man, the “limbic” system. In recent years this area has received popular designation as the “old mammalian” or “visceral” brain (MacLean, 1973). It has undergone increasingly precise reductive analysis at the cellular, molecular, and functional levels and its popular designation as the “mammalian” brain has changed as its role in higher cortical function has been elaborated. In man the limbic system has been found to be important in memory, selective attention and emotion, and it has functional connections to the cortex, including parts of the frontal lobes and the language system, which still need to be clarified. It is this set of findings, concerning early man, his art, his capacity, his culture, and his brain, that we will discuss today.

In 1868, the French government was building a railroad from Paris to the isolated farm areas around Les Eyzies. Landfill was needed to build a railroad bridge across the Vézère River, on which the village sits pressed against a high limestone cliff (Fig. 2). In

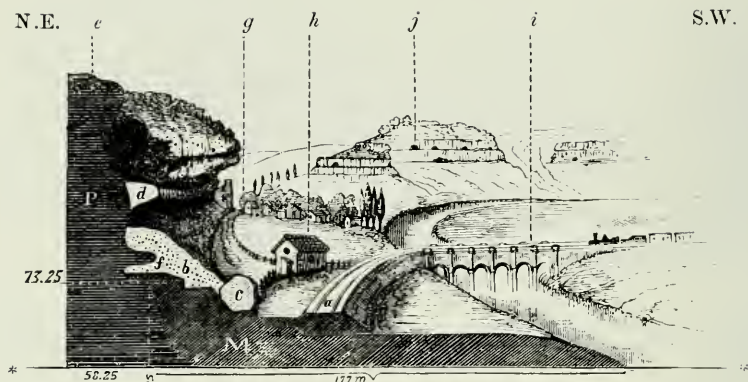


Fig. 3. The cave of Cro-Magnon, uncovered while digging for landfill for the Les Eyzies railway bridge (after L. Lartet, 1875). Abbreviations: a, railroad; b, talus; c, great block of stone; d, ledge of rock; e, rock of Cro-Magnon; f, cave; g, château and village of Les Eyzies, in the valley of the Beune; h, gatekeeper's house; i, railway bridge over the Vézère; j, Caves of Le Cingle. P, limestone; M, detritus of the slopes and alluvium of the valley.

digging for landfill at the base of the cliff (Fig. 3), the workers uncovered a cave containing the skeletons of the makers of the tools and art that Lartet had been finding in the area. With the skeletons, in fact, were incised images and necklaces of seashells that came from both the Atlantic and the Mediterranean. Lartet's son, Louis, was commissioned to verify the authenticity of the excavation. Broca was given the skeletons of Cro-Magnon to study. I quote from the paper that Broca read to the French Society for the Advancement of Sciences in 1872.

The skeletons of these robust troglodytes (or cave-dwellers) bear traces of the violence of their manners; in the lower extremity of one of the femurs of the old man is a hollow similar to that produced in our day by a spent ball. It is evidently the result of an old wound received, perhaps, in the chase; perhaps in war; but a human hand, armed with a flint instrument, must have produced a long, deep aperture which appears in the skull of the woman (Fig. 4); the width of the opening shows that the brain must have been injured, but still the victim was not killed instantly . . . the skull shows that she survived about 15 days . . . The troglodytes of Cro-Magnon were then savages, but savages of intelligence, capable of improvement . . .

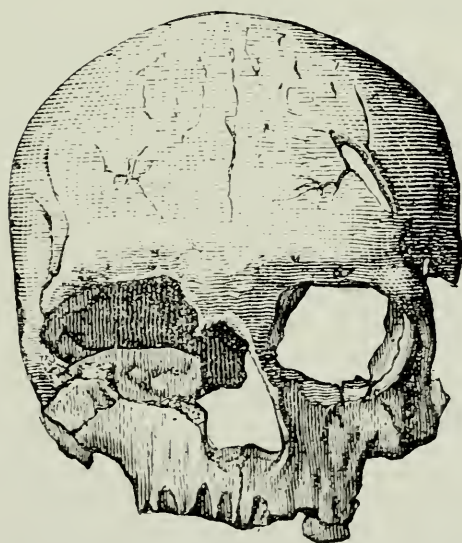
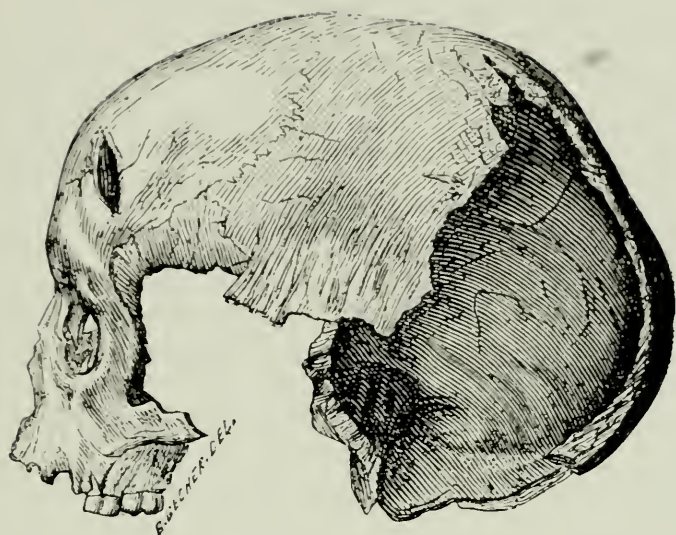


Fig. 4. The skull of the Cro-Magnon woman showing the deep cut (after Broca, 1872).

I do not know if Broca meant “improvement” to modern historical standards, since in the realm of violence that would not constitute a great improvement. But Broca continues:

We find among them (the Cro-Magnons) certain signs of a powerful cerebral organization. The skulls are large in diameter . . . and capacity and surpass the mean of . . . existing races The amplitude of the frontal compartment denotes a great development of the anterior cerebral lobes, which are the seat of the most noble facilities of the mind The conformation of their brains show that they were capable of culture These rude hunters of the mammoth, the lion and the bear are the worthy ancestors of the artists of La Madeleine

The Cro-Magnon skeletons of the early Ice Age, c. 28,000 B.C., were some 17,000–15,000 years older than the incised mammoth from the later Ice Age found by Lartet at La Madeleine.

Broca’s discussion of the spear wound in the woman’s skull makes no mention of the limbic or other subcortical systems which participate in human reactions of violence, anger, and killing as well as aspects of the capacity for spatial orientation and memory. In fact, Broca was not to discover and name the limbic system for some years, and even then he would not understand the extraordinary functional complexity of the system which, more than a century later, is still under investigation.

We must be cautious, then, of too simplistic an explanation of the apparent wound in the skull. Perhaps the killing was not “limbic,” but had major input, motivation, and rationalization coming from higher levels of brain function; perhaps it was the result of a ritual or ceremonial act, a sacrificial killing, an act of “justice” carried out, or the result of superstition concerning witchcraft or the breaking of a taboo by that woman. We do not know. We know only that we are dealing with *man* and in man the brain mediates cultural as well as reactive, subcortical responses such as anger and aggression.

In the century since the discovery of the Cro-Magnon skulls, while Broca’s analysis was forgotten, archaeologists have uncovered evidence that the symbolism of death and killing goes back at least to the Neanderthals, 100,000–35,000 B.C., and perhaps to the still earlier human known as *Homo erectus*, c. 400,000–300,000 B.C. The Neanderthals not only buried their dead with symbolic artifacts, including red ochre, animal bones, and flowers, but apparently both

killed and symbolized the dead. At Mount Circeo, in Italy, workmen dug into a limestone hill to enlarge an inn and discovered a cave in which there lay a Neanderthal skull surrounded by a circle of stones. The skull had "one or more violent blows on the right temporal region that had caused conspicuous damage to the frontal and temporal lobes and the zygoma. This mutilation points to a violent death, probably a ritual murder. The other mutilation consists of the careful and symmetric incising of the periphery of the *foramen magnum* . . ." (Blanc, 1961). Still earlier human skulls from Europe show a similar widening of the *foramen magnum*. At the *Homo erectus* cave site of Peking Man, at Choukoutien, China, c. 400,000 B.C., the fragments of 40 human skulls were found with only a few limb fragments, suggesting some level of choice or symbolization. Recently, a far earlier hominid skull was found, in Bodo, Ethiopia, that had cut marks made with a stone knife below the left eye socket and on the frontal bone, suggesting intentional removal of the skin from the face and head. Whether this was an act of limbic "aggression," an act of "cannibalism," or a symbolic act of "sharing" in the spirit or person of the deceased (and therefore an act of reverence), we cannot tell. But in any case, it involved an intentional act related to the death of a conspecific that may have had an element of symbolic, if nonlinguistic, meaning.

Whatever aspects of the symbolism of killing and death that did exist in the cave at Cro-Magnon were apparently prepared for in earlier periods of human evolution and culture. In all such early instances, it was not the aggression and violence that were significant but the possible beginning acculturation and symbolization of the act or process of killing and the uses of death. One of the findings of the present program of research into Ice Age art and symbol is that images and uses of death had become extremely variable and complex by this period. With this introduction, we can turn to an analysis of certain specialized aspects of Ice Age art and symbol, the only body of materials in which the full range of higher cortical function is evident.

During the last Ice Age, one-half of Europe was covered by a sheet of ice a mile and more thick. Half of Germany, England, and all of Scandinavia lay under the ice sheet. So much water was locked up in ice that one could walk from England to France. During this

period the Cro-Magnon hunters lived primarily along the network of rivers that flowed from the great ice sheets and the mountains and hills, either westward to the Atlantic, or south to the Mediterranean and Black seas.

When I began my research some 20 years ago it was held that modern *Homo sapiens* had walked into Europe some 35,000 years ago, displacing the Neanderthals who had lived there for the previous 75,000 years. These Cro-Magnons carried a new skeleton, a new tool kit involving a large use of bone, and the first art to be found anywhere on earth. These beliefs have changed during the period of the present research.

I present the analysis of some examples of Ice Age art excavated in this century. The carved horse of mammoth ivory, only 2½ inches in size, is the oldest animal image known (Fig. 5). It is 32,000 years old and comes from the early Aurignacian, the period of the Cro-Magnon skeletons, but it is nevertheless some 2000–3000 years older than the skeletons. It was found at the small habitation cave of Vogelherd in Germany.

The first thing to note is that, though this is the earliest example of representational art known, it is not “primitive.” It is, in fact, extraordinarily sophisticated. This is not the way the Ice Age horse looked, for it was short, stocky, and had a thick muzzle and neck and a stubby body. The image, therefore, is an abstraction of “horseness,” depicting the characteristic movement and feel of the species. This capacity to abstract an image, form, and species character, was, as we shall see, one of the crucial nonlinguistic, adaptive, symbolizing capacities of the early human cultures.

When I began my research, such animal images from the Ice Age were generally considered to be aspects of “hunting magic.” It was assumed that Cro-Magnon, as a hunter, made an animal image, went through the act of “killing” the image, and by this act of sympathetic magic, went out and hunted with greater assurance of success.

When I put the carved horse under the microscope, data contradicting this view emerged. The eyes, ears, nostrils, mouth, mane, and tail had been carefully carved, but these were worn down and polished from long handling. Since this was ivory, the handling involved, if the statue had been taken in hand periodically for use



Fig. 5. Ivory horse from Vogelherd, Germany, c. 30,000 B.C.

in ritual or ceremony, could have extended over a number of years. At one point in its use an absolutely fresh angle or “dart” had been incised in its shoulder. The dart or wound seemed to represent a late use or “killing” of the horse image. We do not know whether this “killing” was for a curing, a birth, a death, a shamanistic initiation, or perhaps the coming of spring. The evidence of long use and of a single, late, specialized “killing” indicate that the horse was not merely the image of a meal. It was a symbol, made to be used over time in different ways, *one* of which involved a symbolic killing. This “killing” was not subcortical and reactive, but was a cortical, cultural act, probably performed without rage or the impetus of hunger. I have documented the fact that the variable, periodic use of an animal image involving renewal, killing, and association with a range of signs, represented a primary mode in Ice Age art (Marshack, 1969, 1972a, 1972b, 1984b). The variable use of a generic symbol over time, in a range of contexts, represents a modern human mode. It is different from the recent use of images and signs as one-dimensional signifiers in the “proto-language” experiments conducted with chimpanzees and gorillas.

The engraved horse, in fact, was extraordinarily complex. As a carved symbol and image it was, in part at least, a product of right-hemisphere function, since that hemisphere is normally involved in

image formation and in spatial, three-dimensional evaluation. But the long-term, periodic, and specialized use of the horse involved the frontal lobes, which function in cultural planning and in the motivation, maintenance, and evaluation of cultural schedules and behaviors. Simply as a carving, it was the product of another basic capacity of the species, the vision-oriented, *two*-handed capacity for problem solving (Marshack, 1984a). While it was being carved, one hand, presumably the right, engaged in the complex, shifting sequence of carving, while the other, presumably the left, engaged in holding, orienting, and turning the ivory as it was being carved. The right hand manipulated a series of specialized tools in the sequence of cutting, scraping, engraving, and polishing, while the left hand maintained the object in proper orientation, at the correct distance, and with a continuously changing counterpressure to the work of the right hand. From the beginning to the end of the carving process, including obtaining the ivory and the flint for making the stone tools, the essential problem-solving, productive sequences were nonlinguistic. We do not know what level of language accompanied the making and use of the horse, but we can assume that it was sufficient to explain its meaning and use.

The same complexities are involved in other aspects of Ice Age art. The famous "Venus" of Lespugue, c. 25,000 B.C., was excavated in France and appears somewhat later than the Cro-Magnon skeletons (Fig. 6). We have, again, an image of great sophistication, containing an almost modern, 20th century shape and form. This is not the image or portrait of a real woman, but an abstraction and schematization of femininity or "womanness," in much the way that the prior carving was an image of "horseness." The carving has exaggerated breasts, hips, and vulva, with tiny hands and feet and no face. Microscopic analysis of the wear, polish, and different types of overpainting and overmarking on the Venus figurines has shown that they, too, were often intended for long-term, periodic, and variable use. In addition, as a generic symbol, they apparently embodied a range of meaning that varied with each use—concepts relating to fertility, the onset of menarche, birth, the periodicity of menstruation, the dangers of delivery, and the process of lactation. There is also evidence that they were related to the periodicities of flora and

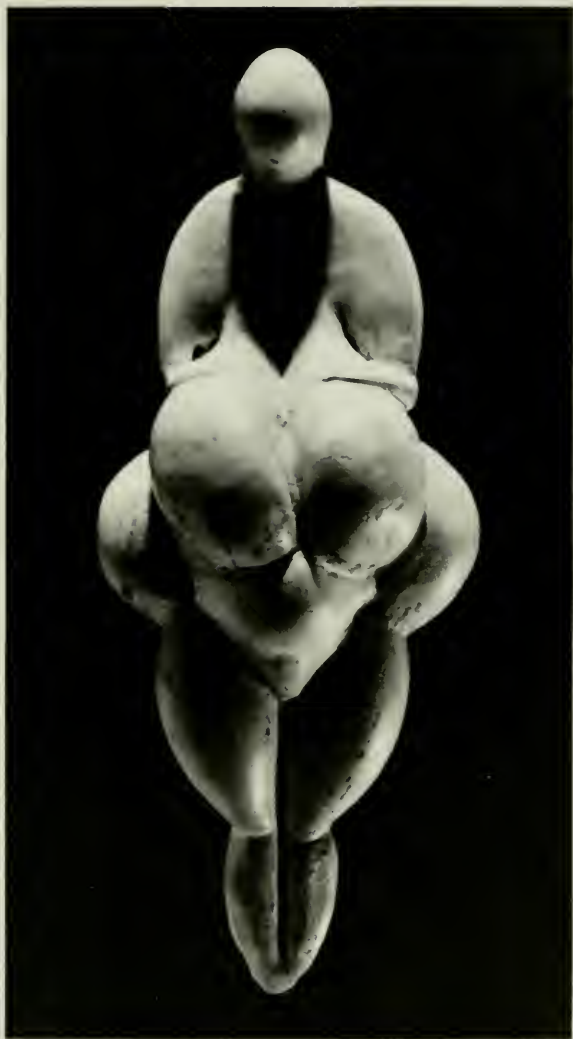


Fig. 6. Ivory statuette of female, the famous "Venus" of Lespugue, France, c. 25,000 B.C.

fauna and in some forms seem to be "ancestor" figures. We are dealing, therefore, not with "art" or representation, but with a core, multivalent symbol. It may therefore be of significance that these



Fig. 7. The village of Les Eyzies as it looks today. Front houses are on the valley floor, houses against the cliff are on a shelf overlooking the valley. Harvard University office is building on shelf at left.

symbolic females were treated differently from the Cro-Magnon woman who, while alive, had apparently had a spear thrust into her skull. Different, that is, in the sense that none of the Ice Age female figurines, were ever symbolically “killed,” though we have evidence of their variable use.

The same two-handed, vision-oriented skills involved in making the horse were involved in making the figurine, though the reasons for making each differed. In each case the productive skills, symbolic processes, and motivations involved were nonlinguistic. The relations of these two-handed, vision-oriented symboling skills to the evolutionary processes involved in hominization and the subsequent origins of language and art, must, therefore, be touched on. To do this I return to the village of Les Eyzies, for that village and its valley were part of the reality and context within which eyes, hands, symbols, and language functioned.

This is Les Eyzies as it looks today, photographed from the bank of the Vézère River (Fig. 7). Ice Age man lived on the high shelf below the limestone overhang. The building at the left is the Harvard University office for the excavation that was under way just behind the house, the Abri Pataud. That excavation, conducted by Hallam Movius, went down to the early Cro-Magnon period of about



Fig. 8. The valley of Les Eyzies as it looks today. The Vézère River below, with the 19th-century railroad bridge. The equinoctial point on the horizon is just to the right of the large farmhouse across the valley at right. The winter solstice sun sets to the left of the smaller set of farmhouses, where the cattle graze. The summer solstice sun sets at far right, out of the picture.

28,000 years ago. The cave of Cro-Magnon itself is about 40 or 50 yards to the left and is now the site of a Michelin starred restaurant and hotel. In the last few years, archaeologists digging at the foot of the rock fall or talus below the cliff have found the tools of Neanderthal man. The cliff shelf above the village may, therefore, have been occupied more or less continuously for some 40,000 or 50,000 years. Not many kilometers from Les Eyzies, and within walking distance of this cliff, earlier examples of man or his artifacts have been found, going back to the period of late *Homo erectus* of about 300,000 years ago. The late evolution and transition to modern man was in large part lived out among these valleys and hills, as it was in other areas.

Figure 8 is a view of the valley as seen from the shelf, standing in front of Harvard's Abri Pataud office. The shelf is oriented due west toward the hills across the valley, the shelf itself running true north and south. Crossing the river is the railroad that was being built when the Cro-Magnon skeletons were found more than a cen-



Fig. 9. Polychrome painting of so-called "Chinese horse" from the cave of Lascaux, France, not far from Les Eyzies, c. 14,500 B.C. Horse is in its summer coat.

tury ago. In the distance across the river, the tiny specks around the farmhouse are grazing cows. Their small size represents the way the browsing herds of bison and horse would have looked during the Ice Age. Inside the limestone hills that form the valleys of the region one finds the caves and the paintings that have in this century become famous as the primary products of the Ice Age cultures. These paintings represent a later tradition than is documented in the Vogelherd horse and the "Venus" figurines. The famous, so-called "Chinese horse" from the cave of Lascaux, not far from Les Eyzies, is dated at about 14,500 B.C. (Fig. 9). Like the earlier carved and engraved animal images, these painted images were originally called "hunting-magic," and for that reason the signs and symbols around the horse were presumed to be weapons and traps. More recently, Freudian interpretations of the long signs as "male" and the wide as "female" have been attempted. We shall look shortly at what these signs really mean and how they relate to symboling modes of the brain.

I first came to Les Eyzies about 20 years ago at the beginning of

July. Professor Movius and I stood on the shelf looking across the valley as the sun went slowly down behind the hills far to the right, sinking as a great red disc. As it was going down, the first crescent of the new moon appeared in the sky as a thin silver arc, facing the sinking sun. It was instantly apparent that the Les Eyzies horizon formed a perfect natural "calendar" and that the first crescent would appear over those hills at sunset every 29 or 30 days. It was also apparent that the sun was sinking at its farthest point north on that horizon, its position at summer solstice, and that it would now begin to move south until it reached a point at which the Vézère River exited the valley between the hills, on its way to the Atlantic. The visual effect of the silver first crescent, aiming its arc at the setting sun and following the summer sun down, was stark and dramatic. There was no way that generations of hunters living on that shelf over a period of 18,000 years or more could fail to notice these periodic changes and movements of the sun and moon. They would have noticed these changes with or without an explanatory use of language, particularly since these visual periods also marked the patterns of faunal and floral changes occurring in the valley. Such observations are well known amongst the world's hunter-gatherers and have been profusely documented in this century. It took the next 18 years, however, before I could properly put together the seasonal and ecological dynamics of that valley and work out its relations to the art, images, and paintings in the caves and to understand the adaptive contents and uses of the art. At the end of the inquiry, I found that I was investigating the hierarchical cross-modal complexity of the evolved human brain and was also inquiring into the adaptive role of symbol, both in language and art. The questions had been incipiently implied, but had never been directly raised, by the pioneering work of Lartet and Broca. I return to the valley.

The Vézère River flows westward to the Atlantic, exiting some 150 miles to the west, in the estuary beyond Bordeaux. The river flows south at Les Eyzies and turns west between the hills at the end of the valley. When the setting sun reaches this low point at the winter solstice, we are in mid-winter, the days are short, and the sun sets early. From the winter solstice on, the setting sun begins its march back toward the north. When it reaches its midpoint on the

horizon, it is the time of the spring equinox around March 21. The winter was over and the thaw and flood were about to begin. This was only some three or four first crescents after the first frosts or snows had descended on the valley. A few weeks after the thaw, the Atlantic salmon began to come up river on their yearly spawning run, arriving by the thousands. They spawned in the many small tributary streams of the Vézère, one of which, the Beune, flowed into the river at the foot of the cliff where the hunters camped. That spring run of salmon would have represented the first large availability of fresh meat after the hardship of the winter.

At about the same time, a few days or weeks after the thaw, the reindeer would have begun migrating through the valley, arriving from the lowlands toward the westward coast and heading for the cool hills to the east, behind Les Eyzies, for summer pasture. The herds would probably have crossed the Vézère at the point where the railroad bridge stands, since it is built on a low point in the river created by a natural geological fault and ford (White, 1985). The arrival of salmon and reindeer, when the setting sun was at midpoint on the western horizon, marked the beginning of the abundant half-year. Six months later, at autumn equinox, a few weeks after the sun had again reached that midpoint, the reindeer herd would come back across the river, this time heading west, for lowland pasturage without troubling insects. It was probably at this crossing point and time that the Cro-Magnon hunters of Les Eyzies killed the summer-fattened reindeer, not only for their meat and fat, but for their fall skins and their autumn antlers. The reindeer were not only food but a major resource of working materials and hides. Throughout the year other animal species would also have been moving through the narrow river valley or on the flat plateau above, following the shifting availability of plant growth.

About 10 minutes by foot up river from Les Eyzies, on the other side of the river, is a site that Lartet first excavated in the 1860s, a habitation cave in the small Gorge d'Enfer. A tributary stream flows through the gorge. Carved on the ceiling of the small cave is a 3-foot-long salmon, a clearly represented male salmon at the time of the spring run with the typical hook or "kipe" on the lower jaw that is found only on the male at this period. I have published this image

of the male salmon from many Ice Age sites, including those north of Les Eyzies and those as far south as the Pyrenees (Marshack, 1970, 1972a, 1975, 1985a).

It was in the Gorge d'Enfer that Lartet excavated an unusual bone plaque marked on both faces with sets of dots and lines (Lartet and Christy, 1875). It was this plaque that initiated my own investigation of the cognitive content in the early Ice Age symbol systems. The plaque was originally published as a possible "tally," presumably of animals killed. When I first came to France to begin my inquiry, it was to study this strange plaque and the others like it that had begun to be found in all periods of the Ice Age. We shall analyze one shortly.

Downriver from Les Eyzies, about a half-hour drive by car, the Vézère enters the Dordogne, which then flows toward Bordeaux and the Atlantic. At the junction of the two rivers there is another shallow area, or ford, where reindeer herds crossed during the Ice Age. Overlooking the ford was a habitation site on a hill called Limeuil. Here, engraved on broken pieces of limestone that had fallen from the shelter wall, over a hundred images of reindeer and other animals were found. These depict the differences in male and female reindeer at the time of the spring and autumn migration; they include spring calves, the male reindeer in the autumn with a full head of antlers, head up, mouth open, braying in the time of the autumn rut. It is a few weeks after the autumn rut that the male drops his antlers, while the female retains hers through the calving in the springtime in order to protect the calves. These differences were all depicted. Again, I have published a large body of such images depicting the sexual and seasonal characteristics and behavior of different species in the art of the Ice Age (1970, 1972a, 1975, 1985a).

It was Lartet who had begun the consistent excavation of these animal images, as well as the tools and the remains of meals. But it was his so-called "tally" that had initially intrigued me. About 15 or 20 minutes upriver by car from Les Eyzies, at a riverside site called the Abri Blanchard, a small plaquette was found in the 1930s that was similar in size and shape to the one found a short distance away by Lartet in the Gorge d'Enfer. This plaque and the one from the Gorge d'Enfer were lying together in the Musée des Antiquités National, outside of Paris, when I began my studies. They both came

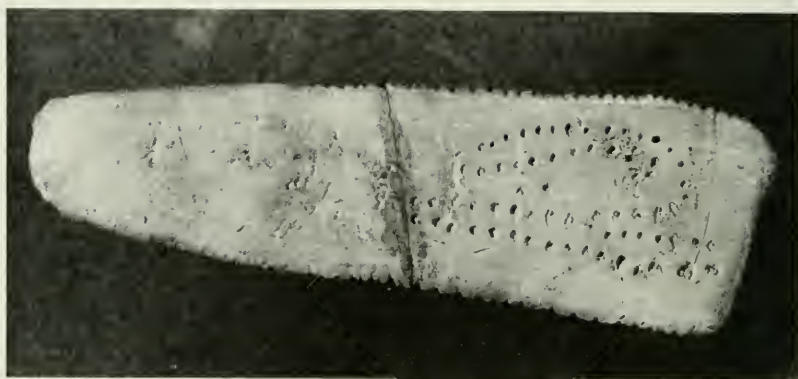


Fig. 10. Carved bone plaque from the habitation site of Blanchard, France, not far from Les Eyzies, c. 28,000 B.C. The surface has a sequence of marks determined to be notational.

from the same early period of the Ice Age as the Vogelherd horse, the “Venus” figurines, and the Cro-Magnon skeletons.

The Blanchard plaque (Fig. 10), originally published as a “polisher,” was presumably intended to smooth leather and was decorated with what was described as a meaningless or random pocking. Microscopic analysis revealed that it was not a polisher and that it was not decorated. Instead, the analysis revealed that it represented the most complex single problem-solving artifact of that early period of human culture. The plaque (10 cm long) was just large enough to be held in the hand. It had high polish at the rear where it had pushed against the palm, but it was broken back at the front by persistent pressure occurring during the fine retouch of flint tools. It was, then, a pressure flaker and the amount of polish in the rear and frontal breakage suggested that it had been used for a considerable period, perhaps of some months. Microscopic analysis further revealed that the pocking in the small center area (4.4 cm) was in reality an accumulation of 69 marks that was broken down into 24 *sets* of marks, ranging from one to seven units each. Each set was made by a different tool or point and with a different type of stroke, some punched, some arcing to the right, some to the left (Marshack, 1970b, 1972a, 1972b, 1975).

The analysis revealed that the accumulation began in the center

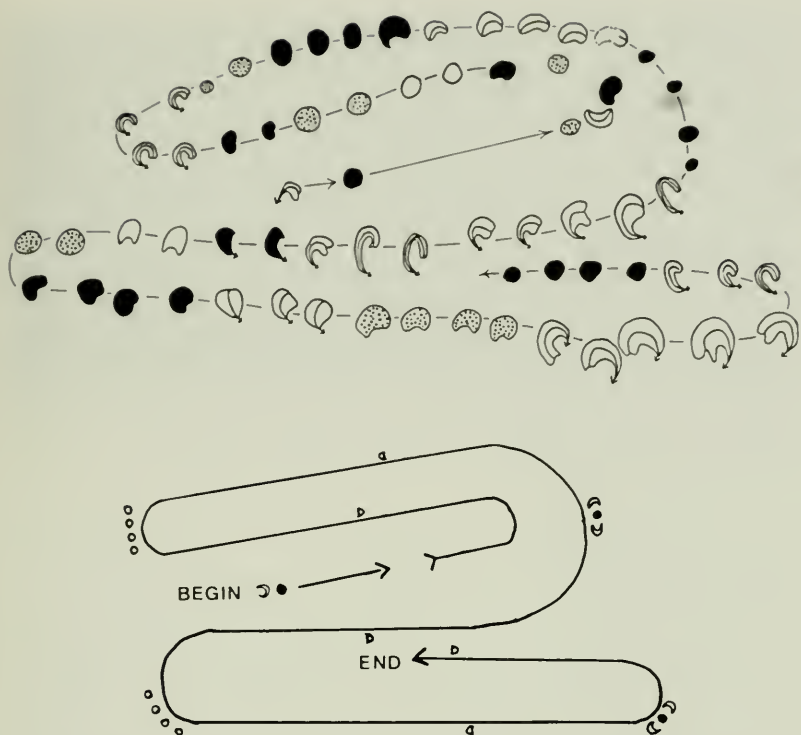


Fig. 11. Schematic rendition of the incised marks on the Blanchard plaque. The 69 marks are made in 24 "sets" in different styles and by different tools, forming a serpentine image that models the waxing and waning of the moon.

of the marking and proceeded set by set in a serpentine manner, with two turns occurring at the left and two at the right (Fig. 11). Because of the many changes of tool and stroke, the accumulation of sets had clearly occurred over a period of time. It was apparent, therefore, that this was some form of notation, made some 20,000 years before the invention of formal recordkeeping or writing in the later agricultural civilizations of the Middle East. Internal analysis of the sequence indicated that the Blanchard engraving apparently represented a nonarithmetic, observational lunar notation covering a period of $2\frac{1}{4}$ months, with the turns occurring at the major changes of phase in the lunar month. All the full-moon periods fell to the

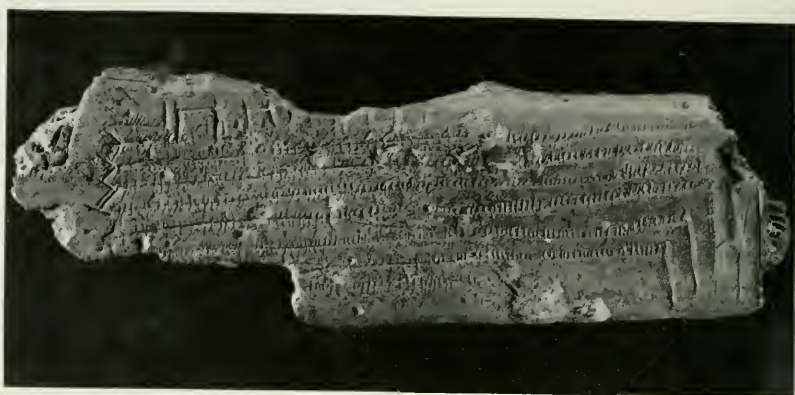


Fig. 12a. Bone plaque from the Grotte du Tâi, France, incised with a sequential, boustrophedon notation. Terminal Magdalenian period, c. 9,500 B.C.

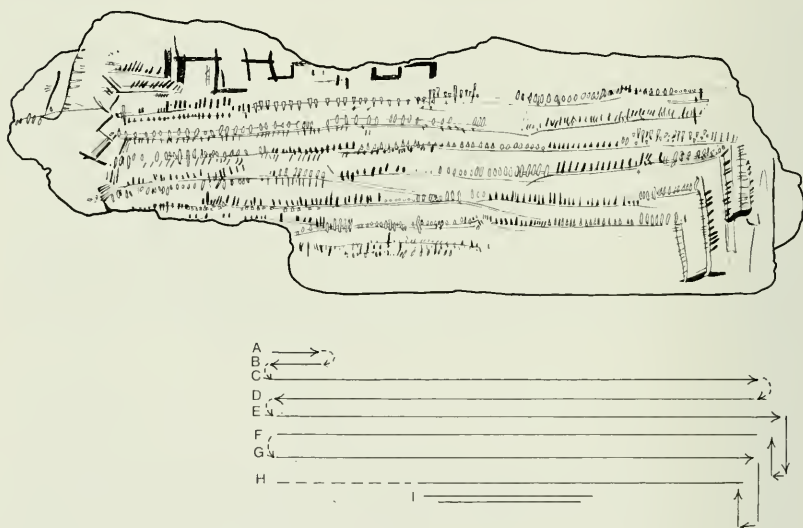


Fig. 12b. Schematic rendition of the marks on the Grotte du Tâi plaque, indicating the subsections and the marking on the descending lines at the end of rows E-F and G-H.

left; all the periods of crescent moon and invisibility fell to the right; and the half-moons fell in midline.

Cognitively, within a single artifact, we had two types of “tool,” one practical and one conceptual or ideational, each of which func-

tioned differently and with different patterns of neurological specialization. This mode of creating multiple and variable functions in a single artifact is well known among hunter-gatherers. The Blanchard plaquette had apparently been made by someone who carried it about as a portable item, perhaps in a pouch, to be used for sharpening or shaping stone tools and during that period had used the available surface for notating the passage of time. The plaquette found by Lartet in the 1860s, on the same river and just a few kilometers away, was of the same type, except that the engraver had made use of the edges as a containing line for his sets and had therefore accumulated them in a somewhat different manner (Marshack, 1972a, 1972b, 1972c). It was the analysis of the Blanchard plaque early in the research, and the analysis of the one from the Gorge d'Enfer which also contained the springtime image of a male salmon in the time of spawning, that provided an early clue as to the possible relationship of the animal art of the Ice Age, with its developing realism and its descriptive sexual and seasonal detail, to the calendric notations. The notations and the animal images functioned as interconnected referential symbolic modes.

The Blanchard plaquette was engraved at the beginning of the last Ice Age, c. 28,000 B.C. Some 18,000 years later, at the end of the Ice Age, when the climate was warming, when the mammoth had disappeared from Europe, and when the hunting-gathering cultures of the Ice Age were on the verge of drastic change, a similar plaque was engraved at another site in France (Fig. 12a). Excavated in the 1960s, the engraving was so complex that, after I had developed the microscopic method, the excavators requested I come to France to study it.

Microscopic analysis revealed that the plaque (8.6 cm long) from the Grotte du Tâi was originally a working tool, perhaps a pressure flaker, that had been broken at the left. It had then been cut at the right and a bit of bone had been snapped off, not quite cleanly, to make a small, portable slate that could be used for marking. At first glance it seems that the plaque is incised with nine or ten horizontal lines (A to I on Fig. 12b). Microscopic analysis of the engraving, however, revealed that these were not single horizontal lines, but that each horizontal was composed of short sections, one appended

to the other and often overlapping. Each of these subsections was marked with its own set of tiny marks. Analysis of the marks in each subsection revealed that they were made by different tools and with a different rhythm of marking from that of adjacent subsets. Some sets were incised upward and some downward. There were other indications of cumulative marking. At the beginning of a row there tended to be ample space for the marks, but as the accumulating sets approached the end of a horizontal row, they began to crowd together, as though the engraver had run out of needed space.

At the far right, near the break, there were two right-angle descents. They occurred at the ends of rows E-F and G-H. Each of the descending lines was connected to an ascending line by a horizontal bar, and both the descending and ascending lines had been incised with sets of tiny marks. Apparently, the engraver had not planned well, for extra marking space was needed at the end of row E to complete a marking sequence to a certain required length. Having added a descending line, the engraver was forced to take account of the lack of horizontal space for the next set of rows (G-H) and do the same. This was not the way a "decoration" would have been marked. We had, in fact, found a problem-solving strategy that provided a clue to the direction and mode of marking. The marking represented a serpentine or boustrophedon notation that was conceptually in the tradition of the earlier Blanchard plaquette. This main face notated $3\frac{1}{2}$ years, 6 months on each long horizontal, with the turns coming at the solstices. On the reverse face there were additional sequences of notation marked on horizontal subsections, totaling approximately 5 to 6 months (Marshack, 1973).

The two-handed, vision-oriented capacity and the cognitive, spatial, observational, and notational problems to be solved were similar in the Blanchard and the Grotte du Tâi notations, except that we have evidence of a developing complexity during the 18,000 years between the two. By the end of the Ice Age, the notation of lunar periods and months had been extended to the marking of a longer, more inclusive lunar-solar "year" as a relevant concept. I assume that by the end of the Ice Age the "year" as a conceptual frame had become practically, ritually, and mythologically signifi-

cant in Cro-Magnon culture and I have begun to document the nature of that historical development elsewhere (Marshack, 1984).

Here I wish to examine a few of the hierarchical neurological capacities involved in the notations and to inquire into their relevance for our understanding of the selective evolution occurring within the human brain for certain types of cross-modal, associational function, involving vision, tool use and manipulation, abstraction, sequencing, and image formation. Both notations were a product of the evolved, two-handed, vision-oriented capacity for variable problem solving. The strategies evident in the two plaques, however, were of different types and occurred at different levels of reference and abstraction.

When the Blanchard plaque was being used as a pressure flaker or retoucher, each hand was engaged in a different set and sequence of problem-solving strategies. These involved separate sensory perceptions and a differentiated manipulation and handling of the objects held in the right and left hands. The process involved continuous feedback and evaluations and judgments of the different ongoing actions of each hand. The total process, mediated at both the tactual and visual levels, was being conjointly evaluated at subcortical and at right- and left-hemisphere cortical levels. Presumably, the right hand, grasping the plaque as a pressure flaker, performed the specifying action of chipping or flaking the flint tool being held in the left hand. The left hand, holding the flint to be sharpened, was carrying out the orienting and grasping action, shifting and turning the flint as it was being worked, and with each specifying action of the right hand, providing the proper measure of counter pressure for the bone flaking tool. Watching a toolmaker at work during pressure flaking would make it clear that two separate but coordinated strategies and sequences of motor skills are being performed by each hand.

The two-handed, lateralized, vision-oriented, and tool-mediated skills involved in working a piece of flint are, in general, similar to the two-handed problem-solving skills involved in carving a chunk of mammoth ivory into a horse or figurine. The intent and problem-solving strategies, however, are different. In carving an image, a

changing set of flint tools is held in the specifying hand and it is the ivory, held in the other hand, that is being worked or shaped. In pressure flaking it is the bone that is held in the specifying, dominant hand and it is the flint that is being shaped. The same hands, eyes, and brain mediate both sequences, but the strategies are different and are intended to achieve different ends. When the bone was used as a pressure flaker, the intent was to achieve a utilitarian cutting edge. In the case of the carvings, the intent was to produce a non-utilitarian, symbolic artifact whose meaning was in the form. When the bone was used as a pressure flaker, it was a secondary tool being used to make a primary tool, the cutting edge. The skills involved in creating a cutting edge go back at least to the early hominid, *Homo habilis*, of some 2.5–3 million years ago, when the first crude pebble tools were made by use of a hammerstone held in the preferred hand, knocking off flakes from a pebble, probably held against the ground by the secondary hand. The use of a bone hammer or pressure flaker for the fine retouch of an edge appears to have begun with *Homo erectus*, some 1–2 million years ago. The brain and two-handed capacity had by then evolved, as had the range of tools, tool use, and materials being worked. Though there was now a qualitative difference in the capacity of the two hands, the essential two-handed problem was the same as that for the chipping of the pebble tools. Therefore, as a fine retoucher, the Blanchard bone stood at the end of a long neurological and cultural development.

When the Blanchard bone was being used not as a pressure flaker, but for *notation*, however, the hands and the problem were reversed. The bone was now probably grasped in the *secondary*, nondominant left hand, while a flint engraving tool (which may have been shaped or sharpened by the same bone plaquette), was now being held in the right hand, where it served as a stylus for incising an accumulating sequence of abstracted units or sets. This notation was not writing, since the units and sets were nonlinguistic, and it was not arithmetic since the sets and the combination of sets, though quantitative, were not counted or summed. Nevertheless, the problem-solving processes involved in structuring and sequencing a notation, were of the same order as, and incipient to, those that would be found in the later development of writing and arithmeticized rec-

ordkeeping. In the Cro-Magnon cultures of the European Ice Age the social need and the historical preparation necessary for formal writing and arithmetic were not yet present.

I now go to a different level in our analysis of the hierarchy of variable cortical functions apparent in the Ice Age notations. The Blanchard notation was accumulated in a serpentine manner with the “turns” coming at the two points of major observational change in the lunar month—the period of the full moon and that of the crescents and invisibility. I assume that the image was created as a result of the *ad hoc* problem solving faced by the engraver who was attempting to accumulate a continuous, sequential notation within a limited two-dimensional space. The places of “turning” in such a case would fall naturally where the phases themselves changed during the waxing and waning of the moon. Linguistically, we also refer to these as points of “turning,” and in the folk mythologies of different peoples these are recognized as points of turning in tales told about the phases of the moon. Having completed the Blanchard notation, the engraver not only had an image of the waxing and waning of the moon, but he had also created an abstracted image of the continuity and periodicity of time itself. Anyone in the culture seeing the image and knowing the tradition would probably have seen in the serpentine pattern an image of the periodicity and continuity of time, without having to “read” the individual units and sets. The number and arrangement of sets would have varied with the notation of each engraver. In the Blanchard notation, if each single mark is the abstraction of a day, and each horizontal section or phrase is the abstraction of a lunar period, the final serpentine has, in effect, become an abstraction of periodic time and process. It is significant that the image was not derived in advance as a “concept” but was probably derived from the *ad hoc*, linear sequencing process and what was apparently a traditional observation of the waxing and waning of the moon.

In much the same manner, the longer serpentine or boustrophedon notation of the Grotte du Tâi plaque, made 18,000 years later at the end of the Ice Age, can be read as an image of the “year.” The summer solstice at the right represents one point of “turning” and the winter solstice at the left represents another point of “turning”

and, in addition, the end of one year and the beginning of another. Above the Grotte du Tâi serpentine notation (Fig. 12) is a right-angle meander which, as an abstracted image, seems to say, nonlinguistically, that "we have just completed a notational sequence of which this is the abstract and we now begin another." It may be of interest that the serpentine, the spiral, and the right-angle meander, in the late Ice Age and in many post-Ice Age cultures, tended to have this nonlinguistic, kinesthetic meaning of imaging flow, process, periodicity, and continuity (Marshack, 1984a, 1985a, 1985b).

There are probably no more difficult concepts for human thought than those concerned with time and process. They are at the heart of science, philosophy, religion, and mythology. In the serpentine and the boustrophedon we have an abstraction of periodic time and process that was ultimately derived from the activity of the two-handed, vision-oriented, problem-solving capacity. These are cognized, cultural images and concepts which do not derive from language and are, in fact, not referable to language. Language, if at all, would have referred to the images. These concepts and traditions, based on observation of the processes of the sky and seasons, and on symbolic abstraction and imaging of these processes, were probably as important and adaptive as any supported by language or performed by a cutting edge.

I proceed to the tentative exploration of a still higher level of nonlinguistic, hierarchical abstraction, to concepts which were inherent and incipient in the notations but which were not necessarily apparent to the makers. In the Blanchard serpentine, the full moons fell at the left and the crescents at the right. If we stand facing south and use the period of sunset as our standard period of observation, then all the full moons will rise in the east as the sun sets in the west, all the first crescents will appear in the west as the sun sets in the west, and all the half-moons will appear high in mid-sky as the sun sets in the west. We have in the serpentine, therefore, a topographical or spatial model of the distribution of the phases. The reading is inherent in the model, but like the serpentine itself, it is an end product of the manufacturing process. Whether the topographic model was noted by the engraver, we cannot know. That it is incipient, however, indicates the nature of the nonlinguistic, vi-

sual, modeling, mapping, structuring, and abstracting potentialities being increasingly made possible by the two-handed, vision-oriented, problem-solving capacity.

If we take the Grotte du Tâi notation, we find that the same type of internal "topographic" modeling exists. If our observational standard is again sunset on the western horizon, then the movement of the sun from its low southern point on that horizon at winter solstice to its high northern point at summer solstice images the six-month swing back and forth in the Grotte du Tâi notation. The turns in the notation come at the observational points of turning on the horizon. We do not know if the analogy was noted by the engraver, but the incipience in the cultural product is significant. It is this type of reading and play that at one point began to be utilized by shamans and priests in creating cosmic symbols, mandalas, and "magic" structures and images, particularly in the post-Ice Age cultures. In these later periods, once again, these complex, cognized abstractions were not referable to or derived from language. They were products of the same abstracting and imaging capacities and processes that would later become a part of the development of science.

I am not here interested in the historical processes involved in such developments, but rather in the nonlinguistic, two-handed imaging capacity as an aspect of human neurological evolution. I am also concerned with the manner in which the processes of brain mediation function within changing and developing cultural and phenomenological contexts. For one century, archaeologists largely assigned tools and language the crucial role in hominization. In recent years, other basic biological processes have been added to those considered relevant: changing aspects of morphology such as stance, stride, hips, and teeth; changing patterns of procreation, rearing, and maturation; changing forms of bonding, sharing, and cooperation; changing types of diet; and so on. Almost all these processes, as aspects of behavior, are ultimately mediated and integrated by processes of the brain. In the examples of image, symbol, and abstraction discussed in this paper, for instance, it was neither tools nor language nor any of the patterns and processes of current biological concern that were central, though all in some measure contributed. It was the hierarchically organized mediating brain and the

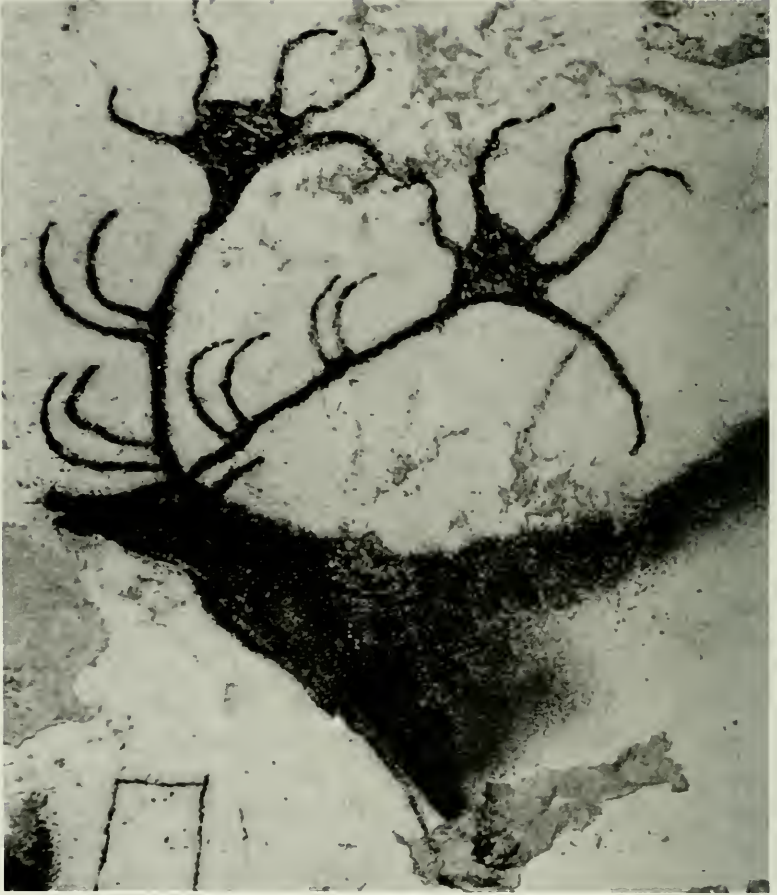


Fig. 13. Painted stag with full head of autumn antlers, head up, and mouth open baying in the autumn rut. The cave of Lascaux (photo, Vertut).

developing complexity of the capacity for problem solving, abstraction, and symboling in different vision-oriented referential modes that were crucial. I will touch on these problems again.

Let us continue our inquiry into the adaptive imaging and abstracting capacity of the Ice Age hunter with an analysis of some of the representational animal images.

In the cave of Lascaux, the best known of the French Ice Age



Fig. 14. Two bull bison from the cave of Lascaux, France. The bison at left is in summer molt, the bison at right is in full winter coat (photo, Vertut).

caves, there is the image of a stag with a full head of antlers, head up, mouth open, baying in the autumn rut (Fig. 13). This is not the image of a meal, but of the male cervid in the limited two- or three-week period of mating time. In Lascaux there is also a well-known panel of two bull bison (Fig. 14) running in opposite directions. In the half-century since the cave was discovered, no one had noted that one of the bison is in summer molt and the other has a late fall or winter coat. Each bison is also painted with a black of a different intensity and was made by a different hand. They represent different seasons, and it is possible that in the summer and fall the bison herds moved through the territory going in different directions. If we now look at the “Chinese horse” (Fig. 9), we can indicate that the horse is in its summer coat, the time when it had short hair and the cream colored underbelly was most visible. In the Ice Age winter, the wild horse grew a heavy winter coat and the demarcation of the underbelly was not as clear. Images of the horse in its heavy winter coat also appear in late Ice Age art. With these few suggestions derived from two decades of research, we can now look at some of the signs with the horse, those “barbed” signs that have been traditionally called weapons or harpoons and more recently “phallic” male symbols because they are long and thin.

In the chamber next to the hall and gallery of paintings is a room with hundreds of engravings. Some are of the type painted around the horse. Figure 15 is the kind of image that had been called a



Fig. 15. Incised image of a fern in the hall of engravings, Lascaux. The image had been called a harpoon and a phallic sign.

harpoon or phallic sign, but it is clearly a plant or fern. A set of engravings from the same hall (Fig. 16) depicts three schematic plants of exactly the type found with the "Chinese horse." For some of the images of Lascaux, we therefore have clear seasonal and sexual representations, associations, and relations. Other modes of representation and of cognized usage have been documented in other



Fig. 16. Set of incised plant forms from the hall of engravings in Lascaux, of the type found around the "Chinese horse" in a nearby chamber.

studies (Marshack, 1984b, 1985b). Here it is important to note that these images, the observations and concepts of which they were a part, and the relations among them were essentially nonlinguistic. They were recognitions derived from the vision-oriented categorizing and abstracting capacity of the left and right hemispheres, though it is likely that such other aspects of categorization as the naming

of the species and the differential details of anatomy, sex, and behavior would have been encoded in language. Language, when used within such contexts, would have been referential, marking categories and processes that were recognized and differentiated nonlinguistically and visually. Language would have served, in such use, as a contribution to what was, in essence, a *visual* form of symboling with its own syntax, modes of use and association, and vocabulary or iconography. The capacity for language and the capacity for visual symboling and problem solving are separate, highly evolved referential modalities, utilizing different areas of the brain, though the evaluation of production in either mode involves equally complex bilateral function. In addition, the making and use of these images at the right time, for the proper rituals, and in the right symbolic context would also have entailed participation of the frontal lobes with contributing input coming from subcortical centers.

The representational images of the Ice Age were all, in one way or another, "time-factored" or "time-factoring" symbols within the cultural continuum. They were highly differentiated, marked images of reference, with relevance either to the economy, to ritual and ceremonial life and mythology, or to social relations within the group. They were symbols made to be used at the right time and place for the proper purpose or to act as continuous symbols through time. Even when symbols and signs were used in personal decoration, they apparently marked sex, stage in maturation, age, status, or role specialization at any moment. As such, the many images and symbols of the Ice Age were corollary referential aspects of the more highly abstracted and specialized notations, with their implied frame of continuity and periodicity. If we examine the seasonal images in Ice Age art from Lascaux or other locations (Marshack, 1970a, 1972a, 1972b, 1975) we can theoretically place them at points on a calendar frame, either as economic, ritual, mythical, or even sacrificial species, or merely as symbols of the seasons themselves. This represents a first level of obvious, visual reference. The meanings of the animal and plant images go beyond such simple recognitions.

Each animal species depicted in Ice Age art (Marshack, 1975, p. 73) had in some degree to be hunted with a different strategy, be butchered or processed with different sets of tools, provided re-

sources or products in different ways, came from a different part of the ecology, and exhibited varied seasonal behavior. These characteristics all had to be recognized and differentiated within a successful hunting-gathering culture. It is likely that within the totally abstracted, notational sequences presented in this paper, the systematic variability of fauna and flora would have formed part of the underlying "deep structure" of the notations and their meaning. We have an interesting problem, then, one that holds also for language and writing. From the point of view of neurological function, it is obvious that the making of the notations could have been disrupted at any of a number of points, by damage to the cerebellum, to primary cortical motor areas in either the right or left hemisphere, by damage to vision or to visual association centers, by damage to orienting and spatial evaluation systems, by damage to the conceptual sequencing and "quantifying" systems of the left hemisphere, or by damage to the frontal lobe planning and motivating systems or their connections to limbic, attentional and affective systems. It is possible that a loss of the ability to name the lunar phases and periods or the seasons would have damaged the capacity to maintain the notations. Loss of the visual capacity to differentiate or categorize the animal species, their uses and behaviors, might have ended the relevance of the notations for a hunter, though the capacity to make the notations remained unimpaired. The capacity for notation was, therefore, like the capacity for language, not merely an evolved localized function, but an aspect of evolved and integrated, hierarchically organized networking processes.

These symbol systems of early modern man bring us back to Broca's finding concerning the localization of aspects of speech production in the frontal lobe of the left hemisphere and to Wernicke's subsequent finding of a specialized language comprehension area in the left temporal lobe. While the complex nature of the neurology of language is being gradually revealed, the nonlinguistic, vision-oriented capacities under discussion in this paper are probably just as complex. They are probably the result of the same trajectory of mosaic hominid neurological evolution, though the processes involved are localized in other motor and comprehension areas of the brain. Language itself, as a referential mode, apparently receives

input from visual association centers (Geschwind, 1972, 1975) and presumably also from those other categorizing, abstracting, and conceptual areas involved in the creation and use of the visual symbol systems under discussion. The underlying deep semantics of language as a referential mode rely largely on the categorizations and evaluations derived from the other sensory and associational modes. It would seem, as a result of accumulating evidence, that a proper inquiry into the human intellectual capacity requires a model of "whole-brain" function and a theory of mosaic evolution of a special type, one that deals developmentally with (1) the changing capacities of the brain for mediation in diverse modes and (2) the nature of the species-specific phenomenological and cultural "reality" that was being mediated by that expanding referential brain.

In the last few years, after analyzing the symbol systems of evolving man going back to the period of *Homo erectus* and Neanderthal man (Marshack, 1976, 1981), I have been forced to consider a model of human evolution in which toolmaking and tool use, symbol making and symbol use, and language are specialized adaptive capacities of a more generalized, hierarchically organized neurological capacity. I have suggested a mosaic model of hominid evolution in which the developing two-handed, vision-oriented competence of a bipedal hominid was a major factor in creating the conditions for reorganization of the brain (Marshack, 1976, 1984a). The model derives evolutionarily and by natural selection from capacities extant on the pongid line.

Field studies of chimpanzees in the wild have revealed that they use their hands in a wide range of tool-mediated adaptive behaviors involving different materials and strategies. Chimpanzees make and use pliable plant probes to fish for ants and termites, sticks to probe for honey, hammers of wood and stone to pound nuts. They correctly judge the weight and type of hammer needed for nuts of different hardness, they crush leaves in the mouth to make a sponge and then use their hands to sop up water from tree notches. They tear off leaves to wipe their backsides, hurl objects at intruders, noisily shake trees and branches in agonistic display, and, as hunters, they capture and rend monkeys as prey. But equally important, they use the hands affectively in hugging, grooming, begging, offering, withholding, and

in the variable range of agonistic "aggressive" displays described above. The hands are, in fact, multivalent and input to handed action comes from diverse cortical and subcortical areas of the brain. Experiments in the laboratory have revealed an even greater range in the "potential variable capacity" of the pongids for solving handed, vision-oriented problems and maintaining interpersonal relations. These capacities are neurologically and morphologically possible, but are never used in the wild.

There is an interesting aspect of this potential variable capacity as it relates to two-handed problem solving. Chimpanzees are largely ambidextrous and can also use their feet as additional, supportive sets of hands. There is a 50 percent tendency to favor one hand over the other in skilled, specifying actions. When the chimpanzee uses a tool in the wild (in ant or termite fishing, sponging, or wiping), the specifying action tends to be one-handed. When two hands are used, however, with or without tools, one hand tends to grasp or hold the object while the other performs the specifying action. As a problem becomes more complex, the tendency for one hand to perform the unfolding sequence of specifying actions, while the other performs the sequence of supporting actions, increases. This tendency is due not only to the two-handed morphology and the nature of lateralized bihemispheric mediation but also to the nature and constraints of the three-dimensional material, physical reality. It is physically impossible for the same hand to both grasp and peel a banana or perform the simultaneous actions of holding a hammer and the nut to be opened. The hands, in cooperation with the eyes, must differentially deal with these aspects of the variable, three-dimensional reality. The sensory perceptions vary for each hand as they evaluate qualities of size, shape, weight, texture, hardness, flexibility, orientation, maneuverability, and manipulability and the sequence as it proceeds and either succeeds or fails.

It is clear that these separate aspects of a complex, three-dimensional sequence cannot be simultaneously handled either by one hand or equally by two hands. The physical reality and the operation call for lateralized performance and sensory evaluation in a two-handed system, even though the sequence is mediated and evaluated by the one set of eyes. These are, nevertheless, relatively simple

aspects of two-handed problem solving. The human mode involved in the accumulation and sequencing of an abstracted notation involves a different order of neurological and referential complexity, which is comparable in its deep structure and semantics to the hierarchical organization found in language. Neurological evolution during hominization has, at one level, worked to increase the acuity and the complexity of the sensory information accruing to any one hand and the complexity of the information accruing to the visual association systems mediating each hand and the two hands jointly. These cross-modal, interhemispheric capacities and processes, while present in the chimpanzee, are not as developed as they are in man. I have suggested that selection for an increase in the neurological capacity of two-handed function would have occurred as an adjunct of increasing bipedality (Marshack, 1984a). The evolutionary problem, however, is not merely neurological and morphological. It also concerns the changing nature and the increasing complexity of the physical and material reality being dealt with or "handled" during hominization and the resulting creation of a species-specific two-handed human culture.

As the young chimpanzee matures, it learns the nature of its manipulable reality by trial and error while handling the materials of its ecology and territory. The complex skills of ant and termite fishing, probing for honey, sponging water, or breaking nuts with a hammer must be learned by example while the young chimpanzee undergoes maturation of the manipulative, coordinating, and conceptual capacities involved. These cultural skills do not occur in all chimpanzee groups and there is variation in skills between groups. Of equal importance, the skills are generalized. They are often seasonal—used only at certain times and in particular parts of the territory. Ants, termites, nuts, and honey are usually seasonal resources, and water sponging is attempted only during the dry season when the pools of water in tree notches have sunk. It is clear, then, that the potential variable capacity for problem solving and culture in the chimpanzee is only partly utilized by any one group in the wild and then only for certain temporal resources in the territory. It is important to note that none of these potential capacities and skills can be deduced from a study of chimpanzee morphology or

brain structure. It is not any particular skill but the range of the potential variable capacity for handed action that is genetic and that capacity varies with individuals within any pongid group. It is probable that in the early stages of hominization selection occurred from within the pool of genetic capacity and variability present in a pongid group.

There is another side to this problem. Some of the potential capacities of the pongid have been uncovered only in the laboratory. The so-called "proto-linguistic" capacities of pongids for use of different types of visual, hand-manipulated symbols and signs have been tested in the laboratory. What has been tested, however, is not linguistic capacity but certain aspects of the pongid vision-oriented capacity for certain forms of categorization, association, problem solving, and communication. While these capacities are involved in human language, and in the symbol systems discussed in this paper, they are at most incipient cognitive aspects of a prelinguistic capacity in the pongids, and in the tests for a supposed linguistic capacity they can function only in the constrained and artificial "cultural" contexts that are created and maintained for the pongids by humans. By contrast, true language helps to create, is derived from, and helps to maintain the cultural contexts within which it operates. There is, in fact, no human language outside of such cultural contexts. The point is crucial for understanding the difference between those extant, brain-mediated, cognitive capacities which would be incorporated into later and more evolved capacities such as language and visual imaging and symboling systems, and the nature and limitations of these early capacities. A chimpanzee can conceivably be taught to drive a tractor in constrained farming conditions set up by man, but that does not mean that it can create the culture of machinery or agriculture. We are dealing with different orders of neurological and referential capacity and function. It is this neurological and cultural difference that has not yet been investigated in proto-linguistic studies. The chimpanzee, for instance, can learn to draw circles and crosses, and perhaps even serpentines. But the capacity to use these images with the open and variable range of meanings possible to man is not possible for the chimpanzee. The chimpanzee in a man-made laboratory context can learn to gesturally

request a particular tool from another chimpanzee in order to get at an embedded or hidden food, but it cannot create or maintain the ongoing cultural contexts in which a range of tool-mediated behaviors become matters of interpersonal concern. These capacities are at most incipient, and it is from within these incipient and preparatory capacities that selection occurred.

Assuming a beginning for hominization with the bipedal, two-handed capacity that was already present in Africa in *Australopithecus afarensis*, with a brain at c. 400 cc (not much larger than the brain of the average chimpanzee) some 3.5 to 4 million years ago, I have proposed that it was from within the extant pongid "potential variable capacity" and the pool of genetic variation present for such capacity that selection for an increase in the two-handed, problem-solving capacity occurred, the capacity, therefore, for the creation of a hominoid culture (Marshack, 1984a). This is not the same as the presumed specialized capacity for making and using tools, since that is merely one aspect of the more generalized two-handed, problem-solving capacity. The selection proposed could have occurred under conditions of a slowly changing ecology or climate or more rapidly under conditions of regional crisis or stress, such as a continued period of drought or population pressure, or even periodic regional vulcanism. Under such conditions there would probably have been an initial survival advantage for those individuals within a population that were more capable of two-handed *ad hoc* problem solving, with or without tools.

The primary advantage of sustained bipedalism for an evolving protohominid in this model would have resided in the increased generalized capacity for two-handed problem solving, particularly in times of ecological crisis or periodic difficulty. As suggested elsewhere (Marshack, 1984a), the evolutionary process would initially have entailed neurological shifts or changes without necessarily requiring a major increase in brain volume. The foot, for instance, underwent major morphological change, losing much of its manipulability and sensory acuity. The hands underwent comparatively minor morphological change, i.e., the length of the thumb increased in relation to the fingers. However, there probably also occurred major neurological changes involving an increase in both the sensory

and conceptual ranges of two-handed perception, including a greater degree of hand/eye acuity and coordination in both small and large-scale handling. The process would have entailed selection for increasing the capacity for interhemispheric exchange of the hierarchical, vision-oriented, and motoric information involved in lateralized two-handed action.

Under these conditions of natural selection some groups of early hominids would have experienced an increase in the ability to “think” in terms of their changing handed capacity—to see their realm in terms of the potential opportunities it offered and the problems that could be solved in the two-handed mode, with or without tools. The increasing complexity of the physical reality being handled and thought about would have created a growing set of cultural strategies, at first not far beyond those possible for a pongid: digging for roots or tubers with a stick, probing for honey, catching and rendering small animals, scavenging large animals killed by carnivores, breaking bones for marrow, pounding nuts, probing logs or trees for grubs, carrying or cracking eggs, and manipulating plant materials or unworked stones to make a bedding site or shelter. The above activities were probably morphologically easier for a bipedal hominid than for a pongid. But a different class of activities, with or without tools, would also have been easier for a bipedal hominid: two-handed cooperation in lifting heavy logs or stones to hunt for grubs, the cooperative carrying of scavenged portions of a kill, the joint effort required for pulling down branches or shaking trees to secure fruit or nuts at the distant edges, caching stores of nuts safely under a heavy stone to be used at a later time, the cooperative hunting of small animals, the joint construction of common bedding or protective areas.

The proposed model of mosaic neurological evolution suggests that the growing suite of handed skills would have created a corollary knowledge of the seasonal variations in different parts of the territory, a lore that would be marked or “read” by visual signs in the phenomenological world but whose relevance was ultimately referable to the potentiality of the two-handed capacity and technology. A lore also would have developed of the best times of the day for different types of activity in parts of the territory. As suggested

earlier, the handed capacity has a potential that varies widely, one that functions beyond mere subsistence and food gathering. The pongid hands that are capable of agonistic or protective displays in tree and branch rattling would now probably be capable of the controlled, intentional banging together of stones, either by one individual or as a group, to create a sustained racket of terrifying protective noise. There is some indication of this potential for threatening banging, given the materials, among the chimpanzees. I am not suggesting that the strategy was used, since we do not have the evidence, but merely that the potential was present and already incipient on the pongid line. Given an ecology that supplied abundant stone resources and sources of carnivore threat in the open, the opportunities were available. The uses of banging and beating in group hunting, signaling, and music in historical human cultures provide a range of examples of the handed-acoustic capacity in diverse contexts. The potential for using the hands in interpersonal communication also exists in a range of forms on the pongid line.

It was the development of increasingly variable potential capacities, then, both as behavior and skill, rather than the capacity for any particular skill or behavior, that was the primary characteristic of human evolution. It was the increasing range of this variable potential that was to be mediated by the larger, more complex brain. The model suggests that vocalization, or language, in this sense, probably evolved as a *variable* marking capacity in the acoustic mode, comparable neurologically to the potential capacities of the two hands. Current theories concerning the adaptive value of the two-handed bipedal mode, which suggest use of the freed hands for carrying infants or the portage of food to a home site, deal only with certain specialized functional aspects of the developing potential, rather than with the more generalized processes suggested here. Other vertebrates carry infants and bring food back to a home base. The hominids probably began to use their hands in a wide range of interpersonal activities because the hands were now available as more efficient, generalized problem solvers in the new and more variable bipedal context.

The mosaic evolutionary model suggests that it was probably during or just after the adaptive success of the developing two-handed,

vision-mediated capacity had been established that the benefits of an increase in brain volume and neurological capacity would have become apparent, not merely for the sensory and motor skills involved in real-time handed actions and sequences, but for that more important adjunct set of cortical and subcortical capacities that makes the two-handed system in man important in the periodic and variable practical and symbolic programs of culture. These include the many capacities involved in the maintenance of social patterns and interactions and in the evolution of language. Aspects of these capacities have been touched on in our analysis of the Ice Age artifacts. Selection for an increase in these capacities would have occurred at many points in the biological and social process.

It could have occurred at the population level, the advantage of a more efficient two-handed capacity probably being most apparent to a group of hominoid bipeds that found itself in a more difficult or complex ecology (Marshack, 1984a). At another level, the increase in capacity could have occurred by alterations in the rate of fetal development of certain subsystems of the brain, or in changes in the rates of maturation and experiential encoding for different skills. Above all, selection could have occurred at the adult level, screening for those most capable of functioning in an increasingly complex practical and symbolic culture.

Because the two-handed mode was part of a complex, lateralized neurological cognitive system, a generalized system that would serve language as well, the neurological changes that were entrained in hominization would have involved the full set of whole-brain cortical and subcortical capacities. Such capabilities are manifested as selective attention and observation, categorizing, abstraction, imaging, modeling, mapping, planning, creating rules and programs, motivating, coordinating, sequencing, and the still higher capacities for evaluating objects, plans, and actions. These are the generalized capacities that make the specialized skills of the hands and language variable, adaptive, and human. The presence of each of these capacities is apparent in the Ice Age symbol systems. They are among the hierarchically organized capacities that Alexander Luria, the Soviet neuropsychologist, had suggested were involved in the "integration of higher cortical function." These cognitive capacities are

neither "handed" nor "linguistic." However, they provide the deep semantic structure that makes the range of handed and linguistic skills found in man both human and cultural.

This paper began with the nonlinguistic, two-handed, vision-oriented capacity evident in certain artifacts of early man. The mosaic evolutionary model I am proposing suggests that language, as a *referential* mode, would have become increasingly adaptive as a consequence of the general neurological and cultural changes being instituted within a particular group of hominids in an increasingly complex ecological, social context. The model therefore suggests that language would not have been equally adaptive or under equally strong selective pressure for all bipedal hominoids. Those hominoids who became specialized plant feeders in less complex, more stable, and less difficult or variable ecologies, such as the later gracile and robust australopithecines, would not have needed language at the same level of referential capacity. Nor would they have needed a two-handed capacity, and tools or other forms of vision-mediated referential systems at the same level of complexity.

Whole-brain cortical and subcortical function cannot be read from the surface architecture of the brain. Contemporary studies of hominid and hominoid endocasts cannot provide more than a gross indication of those changes occurring in cortical surface morphology that would suggest functional changes in the capacity of handed, vision-oriented problem solving or language. Endocranial studies of the skulls of early man do document the major increase in brain volume, enlargement of the temporal, parietal, and frontal areas, and certain more subtle changes such as a developing asymmetry of the left occipital and a right frontal petalia. Such endocast studies cannot, however, verify with certainty enlargement of Broca's area for speech production in the early hominid skulls. Holloway (1981, 1983) has estimated that the areas of the cortex most likely to have undergone extensive morphological change and enlargement from pongid to human are the parietal lobe, areas of the occipital visual system, and the middle dorsofrontal area. These areas are part of the network that would have been crucial for the development of the hominid visual capacity for symboling and would have supplied some of the referential semantic "deep structure" to language. The

occipitoparietal association area involves the *angular gyrus* which Geschwind (1964, 1972) has suggested is a crucial cross-modal association area for language. It has connections both to Wernicke's area which it adjoins and to Broca's area and the motor areas of the face, by the pathway of the *arcuate fasciculus*. There may also be connections from the *angular gyrus* via the *arcuate fasciculus* to higher vision-oriented association areas of the handed capacity. Geschwind (1967) wrote that "carrying out a task under visual control . . . probably involves a pathway running from [left hemisphere] visual association cortex to motor association cortex and therefore makes use of fibers which also run in the *arcuate fasciculus*." These diverse suggestions, together with the proposed evolutionary model derived from an analysis of the symbolic materials of early man, suggest that development of the lateralized two-handed capacity had become, at some point in the process of hominization, a corollary aspect of the separate development of language in the vocal/auditory mode.

The first clear evidence we have of substantial brain enlargement and of enlargement of major association areas, probably including Broca's and Wernicke's areas, occurred during the stage of *Homo habilis*, around 2 to 2.5 million years ago, together with the first evidence of hammered and chipped pebble tools. By the next stage, a half million or a million years later, in *Homo erectus*, both brain volume and the specialized areas of higher cortical function are greatly enlarged and we have evidence of a more advanced, visually mediated, shaped, and chipped stone tool kit. There is a suggestion of a more complex two-handed culture and therefore a more complex referential need. The mosaic evolutionary model being proposed, however, suggests that it was neither the tool kit nor language, separately or together, that was the central adaptive mechanism in this developing capacity. Rather, it was the hierarchically organized "whole brain function" which was capable of mediating and coordinating the range of potentially variable cultural and practical uses available to these two sensorily and morphologically separate, but ultimately vision-mediated, modalities. The model also suggests, by references to the evidence of complex pongid cultural behavior in the wild and in the laboratory, that selection operated on these

cognitive capacities. These aspects of potentially adaptive neurological function in the pongid cannot be derived from the morphology of the skeleton or the brain. None of the chimpanzee's suite of "cultural" behaviors noted in the wild can, for instance, become archaeological. It is only late in hominid evolution that certain aspects of stone-tool-mediated behaviors become artifactual.

Language, in this model of evolving capacity, can be considered a developing referential function in the acoustic/vocal mode, which became increasingly capable of marking the potentially variable cultural and social milieu, much as stone tools can be considered as functional adjuncts of the two hands in solving a range of problems in the potentially variable material and physical realm. It is at the juncture of these two evolving capacities that we come, neurologically, to those nonlinguistic, visual symboling systems that at some point in hominid evolution become artifactual and with which we began our discussion. These late systems represent modes of problem solving, of reference, and of marking certain aspects of the relevant cultural reality by use of the two-handed capacity and a two-handed technology.

The first archaeological evidence for the manufacture and symbolic use of red ochre, and the possible contemporary symbolic alteration and use of human skulls, appears late in the *Homo erectus* period, c. 400,000–250,000 B.C. *Erectus* was at this stage already on the way to becoming *Homo sapiens*. The mosaic model of a developing potential capacity suggests that these were probably not the first symboling efforts—that they were end products of two-handed capacity and use. The sparse archaeological evidence for the use of ochre and human skulls suggests that these artifacts represent traditions rather than first inventions. Again, the model suggests that such symboling efforts were not intended to serve a particular adaptive, cultural purpose but a potentially variable range of referential and marking purposes. The uses of red ochre, for instance, would probably have varied between groups and within groups. The model suggests that the symboling capacity as a function of brain mediation, expressed through uses of the hands and uses of early language, would have been open and variable. That increasing variability of function would have been made possible by the developing network of cross-

modal, associational, and increasingly lateralized processes being hierarchically organized and integrated in the hominid brain.

The model suggests some of the difficulties encountered in establishing the pongid capacity for using "proto-language" and symbols or for making images of "art" in artificial contexts. In these instances one is testing those aspects of pongid capacity that were incipient and, at most, extant, but were still neurologically insufficient for creating and maintaining the range of abstracted referential uses found in human art and language. The point is crucial for understanding what it was that evolved on the human line and for our understanding of late modern uses of both art and language.

Communication among other species, whether in the visual, acoustic, or chemical mode, almost always constitutes a form of "real" or present-time marking of a constrained, intraspecific relationship or context. The informational, signaling content of such communication can refer to aspects of seasonal sexual behavior; it can involve alarm calls, territorial marking, display behavior, neonate imprinting, and mother-infant interaction; it can facilitate cooperative group hunting or protective activities; it can even involve such examples as the nonvertebrate communication found in bee "language," which provides orienting information about foods available at one point and one moment in the territory. One can add to these "real-time" communications the catalog of primate gestures and vocalizations or the bird song of the male in territorial and sexual behavior during the breeding season. Because of the constrained, intraspecific and context-bound nature of such signaling modes (specific to age, sex, season, and species), they can be largely genetically encoded and experientially and maturationally released.

Human language, however, even at the simplest and most basic level, as evidenced in a child's acquisition of language, marks and differentiates the inherently variable and developmentally changing phenomenological and social reality. From its first words, the child deals with the marked aspects of a variable human culture. Even when a child's language deals with simple ego desires, these develop and change as the child matures within the cultural context. The reason is that human language involves an experiential, maturing neurology that refers developmentally to a changing hierarchically

organized cultural reality. In this it differs from context-bound signaling. It is the neurology of this “open-ended” and variable referential capacity, as it is expressed at the mature, adult level, that interests me in this paper. This interest extends to the neurology of those general cognitive, conceptual, and problem-solving capacities that are involved in the visual symbol systems of the Ice Age and were presumably also involved in language.

This neurology involves the capacity for differentiating and categorizing objects, species, and processes and for the internalized abstracting of forms and processes; it includes the capacity for conceptual mapping and modeling and for planning and performing complex sequences of action and evaluating such unfolding sequences. These are all present at the primate or pongid level, but with a less evolved neurological capacity. I have suggested (Marshack, 1984a) that it was the developing two-handed neurology that helped in the creation of a more complex referential, vision-oriented body of nonlinguistic, functional knowledge and culture, one that would have served the deep semantic structure of language, just as the lateralized two-handed neurology may have served as a conjunctive model for the developing lateralized language capacity. There may be a possibility of verification or clarification of this model in comparative functional and behavioral experiments with primates and humans.

If we now return to our limestone shelf on the cliff overlooking Les Eyzies and look across that valley in evolutionary perspective, we can probably assume that a population of late *Homo erectus*, c. 300,000 B.C., or of Neanderthals of 100,000–40,000 B.C., or of modern Cro-Magnons, would all have seen the same periodic patterns of the sky and seasons with their accompanying changes in flora and fauna, if they lived on that shelf. Climates varied through this period of shifting Ice Ages, but the essential temperate zone periodicities of the seasons and of nature at that latitude in Europe would have persisted. The mosaic evolutionary model suggests that the different types of humans inhabiting that shelf would have “seen” a different relevant practical and marked or symbolic reality. The differences would have been partly due to biology—differences in evolved levels

of neurological capacity among *Homo erectus* and the later *Homo sapiens neanderthalis* and Cro-Magnon, or *Homo sapiens sapiens*; and it would have been partly due to the uses that were possible in two-handed problem solving and an accompanying technology; and partly due to the level of symbolic marking present or possible in each period, whether in speech or in visual modes.

Each group of humans would have noted the sources of raw materials, whether of stones for tools, wood for fire, skins for clothing, meat for eating, colors for symbolic purposes, and so on. However, the social and cultural complexity—the breakdown of that valley and its surround conceptually into areas and periods of specialized seasonal activities and the symbolic and linguistic marking of these abstracted categories of relevance—would have differed. I assume that our Cro-Magnon hunter, after he had lived in that valley for a number of generations, saw it as a structured, dynamic, and patterned whole: he recognized it in terms of the specialized uses possible in different parts of the territory in different seasons. There were probably symbolic zones or areas that were taboo or sacred, such as areas of burial, caves for ritual, or places of a recently remembered tragedy. He could probably locate from that shelf a particular source of red ochre. There may even have been a contact territory up or down river beyond his own territory for obtaining symbolic items, perhaps even by exchange. He had a far more complex set of associations than his Neanderthal or *erectus* predecessors had. Red ochre, for instance, was not only a potential source for decorating his tools, his symbolic artifacts, and himself. It also could be used for decorating his shelter, in burials, in cave painting, in curing ceremonies, and perhaps in preparing skins. It had an increased range of potential variability. It was a material that could be used in times of crisis such as death and curing or in times of celebration and seasonal ritual. The famous early Cro-Magnon figurine, the “Venus of Willendorf,” was heavily covered with red ochre and may have been periodically renewed by overpainting.

There were also other specialized activities that would have been related to the conceptual cognitive map and network of reference maintained by the brain. Our Cro-Magnon notation keeper would have seen the valley and its round of processes in terms of his own

specialized role as keeper of time and the schedule of cultural activities. As a tool maker and tool user he would have been aware of the periodic availability of antlers for making tools and carvings at the river crossing for reindeer below him. He would have been aware of the relation of the position of the early spring setting sun to the spring run of salmon in the river and of the possible relevance of these two events to an aggregation of relatives or neighbors for a feast of the first run. He may have had a name for the sun and moon and a mythological explanation for the processes he observed and the rituals relating to them. Standing on that shelf, he would have known in which direction threats lay, whether from humans or from seasonal storms that arrived with winds from different directions. He could probably read his sky to judge the weather of that day and make his decisions. In every instance, the meaning and relevance of these observations would have been ultimately related to the two-handed competence and the symbolic capacity for differentiating and marking the relevant categories and processes involved. Together these made up the neurologically mediated contents of what we would call his "culture." The potential complexity of this referential realm would have differentiated his culture from that of earlier men who may have stood on that same shelf.

It is more than a century since Lartet and Broca made their pioneering inquiries into early man and the brain. In that century the archaeologists of early man have constructed a rough outline of the time scale and the morphological changes involved in hominization. These have largely validated the original scenario suggested by Darwin. Darwin, however, in the 19th century, could only deal with the more obvious and gross aspects of behavior and morphology. He could not approach the core problem of a changing neurology and potential capacity. Relevant to this problem is the 20th-century archaeological finding that there were at least two diverging lines of bipedal hominoids, evidenced by skeletal and dental differences and a different diet. Different adaptive modes entail different types and levels of neurological mediation. To date, little discussion has been directed to the nature of the neurological differences and capacities that must have accompanied these different hominoid and hominid

adaptations. It is to some aspects of this problem that I have directed attention.

Investigations of primate and human brains have progressed far beyond what Darwin could have conceived. These studies have differentiated many levels of specialized neurological function; they have distinguished dysfunction or abnormality caused by localized damage or surgical disconnection from that caused by genetic factors; they have been able to image certain real-time aspects of whole brain function by tomography or evoked potentials; and they have succeeded in the reductive analysis of single neurons and of synapse function between them. Functional asymmetry in right and left hemispheres and the differences between male and female capacity and neurology are under investigation. However, few of these studies have considered the *evolution* of hierarchically organized "whole brain function" or the relation of the changing brain as a mediating organ to an increasingly complex physical and cultural realm.

Alexander Luria (d. 1977) made a major effort in this direction by his studies of damaged brains. He was largely motivated in his original research by the "Marxist" effort of the pioneering Soviet psychologist L. S. Vygotsky (1962, 1978) to create a theory of the role of the brain, language, imaging, and handed competence or technology in history and culture. Luria eventually attempted to present a unified picture of the adult cultural brain in his *Higher Cortical Function of the Brain* (1966) and his earlier, more tentative volume on psychological modes of thinking in different cultures, *Cognitive Development and Its Cultural and Social Functions* (1976). It was apparently because of this background and his interest in the cultural brain that Luria found the research and inquiry briefly presented in this paper personally relevant. When we met, toward the end of his life, he praised the direction of the inquiry. He recognized that his effort to explain the cultural brain had only partially succeeded. He had only barely touched on the many influences of the subcortical brain and the limbic system on higher cortical function and his major work predated research with split brains and its insight into disassociation of function. Above all, when we met, he stressed the inadequacy of a too simple "Marxism" (Kotchetskova, 1978) in

its attempt to explain the evolution of the brain in utilitarian, materialistic terms related to "labor." Such an approach left out symboling, language, and conceptual thinking. He looked to the new research then under way in neurology to probe more deeply into the role of the subcortical brain and limbic system. He was particularly interested in research that would explore the evolution of "higher cortical function" as the essential mediator and maintainer of culture and as a crucial aspect of and participator in human history and change. He suggested that the fundamental questions I had been asking were of the same type that Vygotsky and he had been exploring from a different direction.

The broad questions, then, concerning man, his brain, and his evolution, which were in different ways of interest to Darwin, Lartet, Broca, and Luria, still remain to be answered. They have been approached from a specialized point of view and with a particular set of data in the present inquiry.

* * *

This paper is dedicated to Norman Geschwind, friend and colleague, who died November 5, 1984, the day on which this manuscript was completed. Geschwind, reading my book (Marshack, 1972a), asked me to present the annual lecture of the Boston Neurological Society in 1974. In the decade that followed he was a consistent supporter of the research and inquiry. As a neurologist interested in the "cultural" brain, he has contributed profoundly to the deepening inquiry. Geschwind presented the James Arthur Lecture in 1980.

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