

Neurophysiology and palaeoart

ROBERT G. BEDNARIK

This paper examines some of the cognitive and intellectual changes that may have led to the ability of hominins to make ‘conscious’ decisions based on cultural percepts or concepts. The human constructs of reality derived from neurophysiological predispositions have not only formed our perceptions of the world, they even appear to have contributed to our physical evolution in the end. Man has been creating his own reality for a long time, and to an ever-increasing degree his world as well, even his own physical image — albeit unintentionally. The original impetus of these developments, the origins of empirically observed changes are considered here. The hard evidence available to us is rather limited, and this is somewhat complicated by the archaeological lack of understanding of that evidence. In its quest to understand cultural entities and evolution, archaeology has focussed on technologies and skeletal changes of hominins over time, two factors that are of very little relevance to cultural studies of the distant human past. A number of studies have sought to overcome that encumbrance, rejecting false archaeological models and taking a closer look at the primary source of empirical information we have — that provided by palaeoart. It may be an advantage to cultural investigation of early human history to replace traditional archaeological practice with a review informed by cognitive science. It thus stands to reason that we need to connect the available palaeoart evidence with neurophysiology.

Encephalisation

The defining process in the evolution of primates and particularly humans is the dramatic expansion of the brain. This immediately raises the issue of the neurophysiology underpinning this remarkable encephalisation that appears to be the defining factor in becoming human. One way to address the question is by recourse to genetics.

The size and complexity of the brain is controlled by genes. Recent research at the Howard Hughes Medical Institute, Chicago, has shown that these genes have undergone much more rapid evolution in humans than in other primates or other mammals. Bruce Lahn and his colleagues believe they have shown that selection favoured individuals with larger brains, enabling them to produce more successful offspring. They focused in their study on four modern species with a presumed common ancestor in the late Cretaceous period, around 80 million years ago: humans, macaques, rats and mice. In particular, they sought to establish how the DNA sequences of 214 specific genes changed over evolutionary time in these four species. Rats and mice are thought to be separated by about 16 to 23

million years of evolution, while humans and macaques seem to have shared a common ancestor between 20 and 25 million years ago. By counting the number of changes in the DNA sequence that altered the protein produced by a gene, the researchers obtained the evolutionary rate for that gene, scaling the changes to the rate of amount of evolutionary time taken to make the changes. This showed that brain-related genes evolved much faster in macaques than in rats and mice, and much faster again in humans than in macaques.

It is thought that the greatly accelerated evolution of these genes in hominins was driven by selection, i.e. the advantages our ancestors derived from a larger and more complex brain were significantly greater than they would have been for other animals. For these advantages to have such distinctive effects, it would be necessary that the individuals equipped with them produced more viable offspring than other genetic mutations. Selective pressures, whatever these were, would then have caused rapid evolution of those genes that control size and complexity of the brain.

To test their model, Lahn and his colleagues divided their brain-related genes into two groups: those involved in the early development of the human brain, from the embryo to the infant; and those involved in the brain’s general housekeeping. Their reasoning was that if their scenario of encephalisation were correct, there would have to be a much faster change in the developmental genes than in the housekeeping genes relating to the brain. That is precisely what they found to be the case, and in the process of this work they also identified two dozen ‘outlier genes’ on the very basis that changes in them are particularly pronounced and accelerated in the human lineage. What is especially striking about these findings is that seventeen of these newly identified genes are specifically involved in determining either the size of the human brain, or its behavioural output. It is therefore assumed that the greatest changes in the human brain during its recent evolution concern those of size, amply demonstrated by the fossil record, and behaviour output. This, clearly, has major implications for understanding the process of becoming human. Ultimately it has to be attributable to selection, and humans were selected in favour of larger brains capable of generating greater behavioural flexibility. This is now thought to have involved many hundreds of mutations in hundreds of genes. After millions of years of this process, its acceleration in the late Pliocene led to the emergence of *Homo*, followed by the rapid brain evolution that has been documented for the entire Pleistocene. It is best explained

by invoking a parallel acceleration in the evolution of both cultural behaviour and social structures, which fuelled the need for greater neural complexity and the relentless selection in its favour.

Lahn and colleagues have confirmed the importance of encephalisation, which raises the question of which of the genes regulate brain size during development. The microcephalin gene is one of them, and the evolution of its protein sequence is thought to have been particularly accelerated during the Pliocene and even earlier. Null mutation in the microcephalin gene causes a congenital effect called microcephaly, in which brain development is severely retarded. Numerous amino acid changes in microcephalin are thought to have occurred during the last 25 to 30 million years, i.e. since our simian ancestry. Another relevant gene is the abnormal spindle-like microcephaly-associated (ASPM) gene, which has also been identified as having contributed significantly to encephalisation during hominin evolution. It, too, is linked to primary microcephaly. Strong selection in favour of this gene is thought to have occurred during human evolution, particularly in the ape lineage leading to hominins. It is perhaps most pronounced in human evolution, i.e. over the last couple of million years. The ASPM gene shows an excess of non-synonymous over synonymous pair substitutions, which indicates intense positive selection. It appears that the rate of advantageous amino acid change fixed by ASPM is in the order of one per 300 000 to 400 000 years. These genes and others are therefore considered responsible for the gradual enlargement specifically of the cerebral cortex.

All of these factors underpin the concept that encephalisation needs to be seen as the key issue in hominin evolution. However, evolution does not plan an end-goal, it merely selects on the basis of improved evolutionary success (Dawkins 1991). By themselves, the factors presented above do not satisfactorily illuminate the process of selection, and there are many other issues to be considered. While the large brain is certainly the most distinctive difference between humans and other animals, and in the context of determining the origins of cognition and symbolism no doubt the most important, we must not neglect to consider all other such differences if we are to understand the process more fully. So the question arises: what are the physiological features that distinguish the human line, and how can they be accommodated in a holistic framework of understanding what occurred during our evolution?

Neoteny

We need to review the phenomenon of ontogenic recapitulation of phylogenetic developments, a possibility first enunciated by Ernst Haeckel in the late 19th century. Humans resemble chimpanzees anatomically most closely in the foetal stage. Both the foetal chimpanzee and the adult human have hair on the top of the head and the chin, but are otherwise largely naked. All male adult apes have a penis bone, but it is not present in adult humans or foetal chimpanzees. In the female chimpanzees, the labia majora are an infantile feature, in humans they are retained for life. The hymen, too, is present in the neonate ape, but is re-

tained for life in human females in the absence of sexual penetration. The organs of the lower abdomen, such as rectum, urethra and vagina, are typically aligned with the spine in most adult mammals, including apes, but in foetal apes and humans they point forward relative to the spine. The human ovary reaches full size at the age of five, which is the age of sexual maturity of the apes. Human hands and feet resemble those of embryonic apes, and the same applies even to their heads. The skull of an unborn ape is thin-walled, globular and lacks the prominent tori (brow ridges) of the adult ape, thus resembling the skull of a modern human. The face of the ape embryo forms an almost vertical plane, as it does in the modern adult human. Even the brains of foetal apes and adult humans are much more similar to each other, in terms of proportion and morphology, than they are to those of adult apes. These many features define the anatomical relationship between apes and man as one of neoteny.

In neoteny, sexual maturity is attained before full somatic development, and juvenile characteristics are retained. In an evolutionary perspective, it refers to species whose adults retain juvenile ancestral features. This has also been called foetalisation, because in such phylogenetic development, foetal characteristics remain into adult life, and certain processes of maturation are retarded (De Beer 1940). Indeed, the modern human is not so much the 'Naked Ape', as it has been called, but rather the 'Infantile Ape' — the ape that has undergone so much selection in favour of neoteny that this retardation should be seen as his second-most prominent characteristic, after his oversized brain. It therefore needs to be considered here.

If we look at these issues more closely, it transpires that these two fundamental aspects of hominin evolution are quite probably related, perhaps through supervenience. It is self-evident that, relative to the neonate ape, the newborn human is not remotely as far developed. For instance, it would find it impossible, for many months after birth, to cling to the fur of a mother for transport. Of course this is related to its excessive brain size, which has caused it to be expelled at an earlier stage of foetal development. Perhaps this implies that humans never had adequate fur for a baby to cling to (contra Caldwell 2008), and it can be regarded as highly probable that human mothers always had to carry their infants. Indeed, one of the first kinds of artefacts used by early humans was no doubt some kind of sling or baby-carrying bag. The long period during which the human infant was entirely dependent upon the mother, not just for sustenance but also to move with the horde as well as for protection, extended the period for learning very significantly. This, obviously, coincided with the continued growth of the brain after birth, which in fact exceeds that of the foetus in man. In the first year after our birth, our brain more than doubles in volume and weight. It continues to grow, approaching adult size by the age of three, but goes on expanding slightly more up to adolescence and even beyond. If we compare this extraordinary development, unheard of in the rest of the animal kingdom, with that of other primates, we see that in simians such as the rhesus monkey and gibbon, 70% of adult brain size is achieved at

the time of birth, the remaining 30% in the subsequent six months. In the apes, the size of the brain approaches adult size after the first year of life. These are very significant differences, and they are connected with our neoteny.

Another marked difference between humans and other animals — in fact all other animals — is the abolition of estrus, or periodicity of libido in the female. This uniquely human feature has not been explained satisfactorily, but there is a good probability that it is also related to human neoteny. The excessively long period of infant dependency would have been mirrored in a similar dependency of mothers on the horde, most especially for the meat protein needed for brain tissue of their unborn (Aiello and Wheeler 1995; Leonard and Robertson 1994, 1996). It is thought very probable that there was strong selection favouring female mutations allowing long periods of sexual receptivity, leading to the abandonment of estrus altogether: those females who were longer or always receptive were favoured in the distribution of meat from kills, in a feedback system facilitating encephalisation through better access to animal protein (Biesele 1993; Deacon 1997). It has been noted that on occasion, female chimpanzees are only given meat after they have copulated with a successful hunter, and it is logical that such a behaviour trait would select in favour of continuously receptive females.

Be that as it may, the numerous physiological features of human neoteny should suffice to demonstrate that the several human species are best defined as foetalised forms of ape. This concept raises the closely related issue of the rapid reduction of robust features in man during the most recent 50 000 years of human evolution. While the process of selecting in favour of infantile physiology appears to mark much of human history, extending over several million years, during the last part of the Late Pleistocene it suddenly accelerated to an unprecedented rate. Worldwide, wherever humans existed 40 000 to 50 000 years ago, possessing as they did an essentially 'Middle Palaeolithic' technological tradition, they shed all of their robust features in just a few tens of millennia. Their brain size decreased, despite the still growing demands made on their brains. Their muscle bulk waned until their physical strength was perhaps halved, in tandem with reductions in bone strength and thickness. The decrease in skull thickness is particularly prominent, as well as rapid reduction in cranial robusticity. This process occurred so fast that it can be tracked through the millennia. At about 35 000 years BP, we encounter gracile specimens in Australia and Africa, and the first evidence of gracilisation is also found in Europe. By 30 000 BP, the skeletal evidence from central Europe presents a distinctive sexual dimorphism: the female crania, though still much more robust than male crania were towards the end of the Pleistocene, show distinctive gracilisation: the development of globular crania, reduction or absence of supraorbital tori and occipital projection, significant loss in bone thickness, and several other features. The males, however, remain almost as robust as typical 'Neanderthals'. Five thousand years later, the females have become markedly more gracile, and the robust features of the males also begin to fade. By 20 000 BP, the

males begin to catch up with the females, and from there on the loss of robusticity continues right to the present time. Males are still more robust today, but a contemporary male is on average less robust than a female of 10 000 years ago. Gracilisation is an ongoing process, and no serious attempt has been made to explain it. Instead, we have been given a tale of replacement (by the African Eve advocates), of which no credible evidence exists. Yet it is obvious that this infantilisation process is essentially what has made us what we are today, more so than any other factor in hominin evolution.

There can be no doubt that the fragility of the skull of contemporary humans, relative to those of the robust humans they derive from in all settled continents, is a significant evolutionary handicap. Numerous fossil human remains show evidence of cranial trauma, and much the same can be said about all other decline humans have experienced as a result of this regressive development. The substantial losses of physical strength, bone density and brain volume are not evolutionary processes; an alternative mechanism will have to be invoked to account for them. It also needs to account for the fact that the process is universal, and if it were the result of mutation one would expect it to radiate from an initial population. This is not the case, it occurs apparently simultaneously in four continents; therefore the cause needs to be found in a universal development. The traditional explanation for it, as the result of a more secure, physically less stressful life, is plain nonsense — like so much else of what Pleistocene archaeology has been propagating. People 30 000 years ago led lives that were not significantly different from those of their ancestors for several hundred thousand years. They hunted, they had encounters with lethal animals and hostile tribes; their daily lives were no more sheltered than those of their predecessors. Significant changes in life styles only occurred with the end of the Pleistocene and the rise of sedentary societies developing agriculture and domestication.

There is one mechanism that defies the laws of Darwinism: Mendel's theory of inheritance. In all sexually reproducing species, all characteristics of individuals are inherited through genes. The principles and mechanisms of genetics apply to the molecular structure of cells and tissues, the development of individuals and the evolution of whole populations. Selective breeding defies natural evolution in the sense that it can rapidly change the characteristics of a population without any natural selection in the Darwinian sense.

In humans, the principal change around 40 000 years ago was not a major shift in life style or diet, it was the rise of external storage of cultural or symbolic information, expressed in a great variety of evidence. This includes markedly increasing technological differentiation, an unprecedented efflorescence of palaeoart, and various forms of other expressions of cultural complexity and increasing differentiation. Forms of storing cultural knowledge external to the brain have been in use for several hundred millennia (Bednarik 2003a), but around 40 000 years ago they appear to have acquired a momentum of their own, for reasons still to be explained satisfactorily. Cultural behaviour

and cultural choices became dominant aspects of human societies (it needs to be emphasised that the term ‘cultural’ is used in its scientific sense throughout, which differs somewhat from the word’s archaeological or everyday use; in science, ‘culture’ refers to non-genetically transmitted practice, i.e. learnt practice). Therein, I propose, lies the explanation for the relatively swift gracilisation of all human populations in Europe, Africa, Asia and Australia — all continents then settled by them.

This demands a revolutionary change in the way we view hominin development in the last part of the Pleistocene. Not only do I reject the entire concept of population replacement, I replace it with a far more realistic hypothesis, and one that has the support of all archaeological, genetic and palaeoanthropological evidence currently available to us. I propose that these described, non-evolutionary but universal changes were culturally mediated. Conscious human choice, evident in various other areas, began to influence breeding patterns, and aesthetic constructs starkly evident in palaeoart production were applied to choosing mating partners. The skeletal evidence from central Europe suggests that this process began with males developing a reproductive preference for females of slightly more juvenile characteristics, whose genetic success only needed to be very marginally greater to achieve the changes the skeletal record documents. As ideas of a sexual desirability that was unrelated to mere reproduction became reified, their effect on breeding patterns would easily account for the progressive female gracilisation we observe. This is then a case of cultural selection for specific phenotypes of juvenile features. Eventually, it also affected the male genotypes, resulting in the reduction of male robusticity that becomes marked during the Gravettian and continues to the present time. In short, this model attributes the process to selective breeding patterns, it defines it as a form of domestication: humans ‘domesticated’ themselves, unintentionally, well before they did the same with other species. This process of human self-domestication can account for the regressive or foetal features that distinguish us from our ancestors of 50000 years ago.

Reviewing palaeoart

Iconicity is the property of a marking or shape that provides visual information recognised by most contemporary humans as resembling the form of an object. A marking or object (referrer) is considered iconic when most modern people tend to see it as resembling a different object (referent). However, iconic resemblance of a referent is not self-evident, its detection requires an appropriate perceptual mechanism. Visual ambiguity, from which this facility probably developed (Bednarik 2003a), is a property widely experienced by species throughout the animal kingdom, but it is thought that only hominins developed a cultural use of this feature. The experience of perceiving, for an instant, a snake on a forest path when in fact there is only an exposed tree root is an example of visual ambiguity, which seems to prompt an alert-reaction caused by a neuronal template. Such visual misidentification, my theory predicts, could in an organism capable of some level of

‘conscious’ reflection lead to perceiving a connection between referent and referrer (or the signified and the signifier). In this theory, the actual production of iconographic forms becomes the cultural and intentional creation of features prompting visual responses to a signifier; it induces visual ambiguity intentionally. This definition of art differs significantly from what is traditionally accepted, and it is crucial in effectively understanding the nature and origins of iconographic art. It is equally crucial in understanding hominin cognition and symboling.

In iconic symbolism, the connection between referent and referrer is via iconicity. This is a relatively simple form of symboling, in the sense that an organism capable of cognitively perceiving visual ambiguity detects at least some meaning without any cultural faculties coming into play. The cognition involved is deeply rooted in mental processes found in numerous animal species, such as flight reactions to the silhouette of a bird of prey, ‘eyes’ on the wings of a moth, or plastic tubing resembling a snake (cf. Coss 1985: 256; Pinker 1997: 386). It is even related to the effect of camouflage, which is just as widespread in natural systems. Some animal species master iconic recognition, in the sense that they recognise a likeness in a photograph or film (Cabe 1980: 324-5), and I have argued that humanness is a function of the degree of competence in perceiving an image (Bednarik 1986). Thus symbolism based on iconicity is cognitively much more rudimentary than a symbolism requiring the link between referent and referrer to be negotiated culturally. For instance, a bead is an object that can have exceedingly complex symbolic roles, but its meaning is only accessible to an organism possessing the software of the cultural conventions concerned.

The acoustic or phonetic equivalent of iconicity is onomatopoeia, which refers to the formation of words by imitating a sound associated with the referent. Typical onomatopoeic words are ‘cuckoo’ or ‘buzz’. With them the meaning is either obvious, or detecting it requires only minimal cultural (learnt) faculties.

In much the same way there are forms of modified iconicity: natural forms whose iconic qualities have been emphasised by anthropic modification. This observation leads to a fundamental differentiation between three forms of symbolism in palaeoart: iconic, modified iconic, and non-iconic. The most direct is by iconicity of purely natural, i.e. unmodified forms. It occurs when an object of the natural world offers sufficient visual clues to prompt the mental bridge to be made between referent and referrer. In palaeoart we have two typical representatives. The first are manuports such as the Makapansgat cobble (Bednarik 1998) (Fig. 1) or the



Figure 1. *The Makapansgat jasperite cobble, deposited 2.5 to 3 million years ago.*

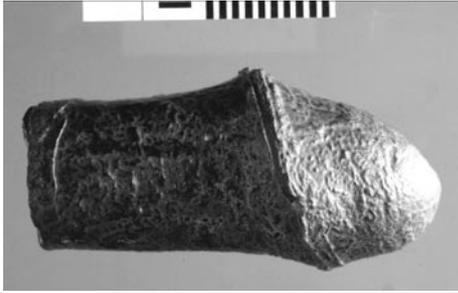


Figure 2. *Acheulian manuport, Erfoud, Morocco.*

Erfoud Site A-84-2 cuttlefish fossil cast (Bednarik 2002) (Fig. 2), which are of such powerful iconic properties that they were noticed by hominins up to three million years ago. Such objects attracted sufficient curiosity to be collected and taken back to occupation sites. The ability to detect such strong levels of iconicity is certainly not very far beyond the capability of the higher pongids, such as chimpanzees or bonobos, so it is reasonable to expect them in australopithecines and subsequent hominins, such as *Kenyanthropus platyops* (3.5 Mya). The second early representative of possible direct iconographic symbolism is via fossil casts, of both floral (e.g. ferns) and faunal specimens (Feliks 1998). Fossils are a prime example of a class of natural forms offering many, if not most, of the visual characteristics of the referent (the live organism, in this case). It seems possible that hominins benefited cognitively from making the connection between referrer and referent in such relatively obvious cases. This could have prompted the establishment of neural pathways permitting the understanding that one thing can stand for another, as well as the appreciation that the objects of the object world can be grouped into classes on the basis of taxonomic criteria. These two abilities were among the most important cogni-

tive milestones in human evolution, therefore they need to be investigated most thoroughly. In my considered view, both appeared at about the same time, and it would be hardly a coincidence if their appearance were accompanied by an apparent quantum jump in technological capacities.

These crucial steps in ‘becoming human’ occurred not, as the ‘short range’ archaeologists would have it, with the advent of their ‘Upper Palaeolithic’ period; they become evident between one million and 800 000 years ago. It is at that time that hominins apparently began to discriminate between ‘exotic’ articles and ‘ordinary’ ones (Bednarik 1990a). It is also then that they left the very first evidence of one of the most important indicators of symboling, the use of pigment (Bednarik 1990b, 1992, 1994a). This coincides roughly with the expansion of humans into Europe, presumably via the Strait of Gibraltar (Bednarik 1999a); it probably coincides with the domestication of fire, and certainly with the introduction of seafaring in Wallacea, Indonesia (Bednarik 1999b, 2003b). The last-mentioned, in particular, tells us a great deal about the developing symboling ability of humans, and in more ways than one. One of the most sophisticated symbol systems developed by our species is of course language, and it is widely agreed that maritime navigation and colonisation of lands by seagoing vessels presupposes relatively complex communication forms, almost certainly of the verbal kind. Since Pleistocene seafaring necessarily involved forward planning and co-ordinated community efforts, it is almost impossible to account for it in the absence of ‘reflective’ language. But there are even more relevant incidental effects. Seafaring is the earliest example we have in hominin history of the domestication of multiple natural systems of energy (Fig. 3). It uses the combined effects of wave movement, current, wind and buoyancy, and it remains the most complex utilisation of energy systems throughout the Pleistocene



Figure 3. *Stone-tool-built bamboo raft off the coast of Flores, Indonesia. This is the eighth experiment undertaken to examine how successful colonising sea crossings of the Lower Palaeolithic may have been accomplished in this region as well as in the Mediterranean. 13 April 2008.*

period. Until the inventions of wheel and sledge, it also remained the only mode of assisted locomotion used on this planet ('assisted' in contrast to autonomous locomotion, as in walking, running, crawling or swimming). It would have promoted the formation of new neural structures on a scale not seen hitherto, such as those supporting 'conscious' awareness of cause-and-effect relationships. This, too, has neurobiological implications for symbolising abilities.



Figure 4. *Acheulian proto-figurine, bearing anthropic grooves and traces of haematite, Tan-Tan, Morocco.*

Subsequent to the realisation that some natural forms can resemble other objects so closely that they can be symbolic for them, a hominin with tactile skills and a good deal of experience in tool use would eventually be tempted to modify such iconic objects to emphasise their iconicity. The oldest finds we have currently of such evidence are the proto-figurines of Tan-Tan (Bednarik 2003c) and Berekhat Ram (Goren-Inbar 1986), thought to be roughly 400 000 and 300 000 years old respectively (Fig. 4). The practice of modifying natural objects to emphasise some iconic

quality has persisted ever since, it can be found through the succeeding periods of the Palaeolithic and it persists today. In a scientific sense it is a subtle management of visual ambiguity: the characteristics of an iconographically already ambiguous object are intentionally accentuated.

This is not to say that symbolising and intentionally modulated communication were the result purely of the factors so far visited. Others are likely to have contributed, and here I would especially like to emphasise the possible involvement of re-enactment, or what is called theatre. To appreciate the role of its symbolism we can easily imagine the return of a successful hunter who revisits his triumph by re-enacting how he stalked the prey, how he slew it. His narrative behaviour in camp would have elicited only bewilderment among his band if they had not shared with him the appropriate neurobiological structures enabling the comprehension of the symbolism he relied upon. In other words, his audience had to possess the facility of discriminating between referrer (his performance) and referent (the hunt he attempted to recreate), while at the same time understanding the symbolic bridge between the two. One could further speculate that symbolising by re-enactment is likely to have originated from neuronal pathways facilitating deceptive behaviour, which has been observed in chimpanzees. Once again, we see that symbol use is based on

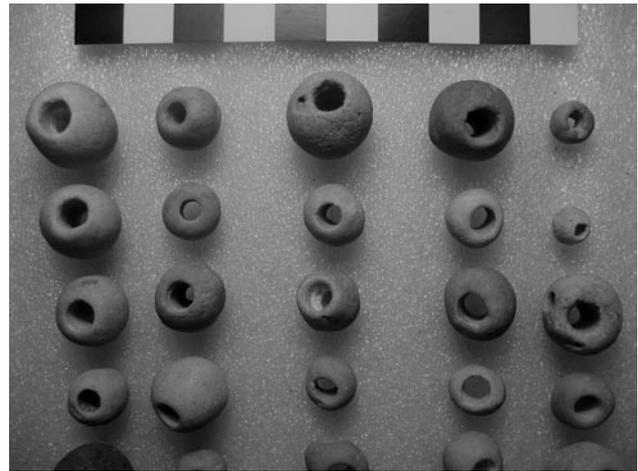


Figure 5. *Acheulian beads from Bedford, England.*

neuronal circuits that may well have their antecedents in those of earlier primates. It is therefore inappropriate to expect finding a specific development or event that would mark the beginning of symbolising. Rather, this must be assumed to be an incremental process, with its origins deep in unconnected neuronal structures that existed even before humans appeared (Fiedler 2003). It was apparently during the Lower Palaeolithic that, in a sequence of developmental events that still need to be identified, various strands or fragments of behavioural traits came together in such a way that what we call 'consciousness' became possible.

The extremely fragmentary evidence of some of these developments has been hinted at above, and some important components of the archaeological evidence have been described (Bednarik 2003). Of particular importance are beads, the significance of which has been considered in some detail (Bednarik 2001). Beads and pendants are among the most obviously symbolic objects we can ever expect to find from the Pleistocene. They tell us a great deal about both the technology and the culture of their makers and users, and they imply the use of cordage. More important, however, are the cultural and cognitive deductions they make possible. Beads of the Lower Palaeolithic are available not only from the French and English Acheulian (Fig. 5), but also from sites in Austria, Libya and Israel. It is therefore inexcusable that they have been consistently ignored by archaeology for more than one and a half centuries. This alone provides enough reason to ignore the models of orthodox archaeology in considering the origins of symbolising. Yet there are still three more types of evidence to be considered here. They are graphic iconic depiction, non-iconic surface markings and the use of colouring material. Oddly enough, the last-mentioned, which is the weakest of the three, is the one that has attracted the most sustained effort (for recent review, see Hovers et al. 2003). Evidence of pigment use, especially of iron oxides and hydroxides, has been tendered for several decades in the support of symbol use, but it needs to be cautioned that it is not necessarily conclusive proof. Mineral pigments such as haematite, goethite and ochreous materials could conceivably be used for utilitarian purposes, although this

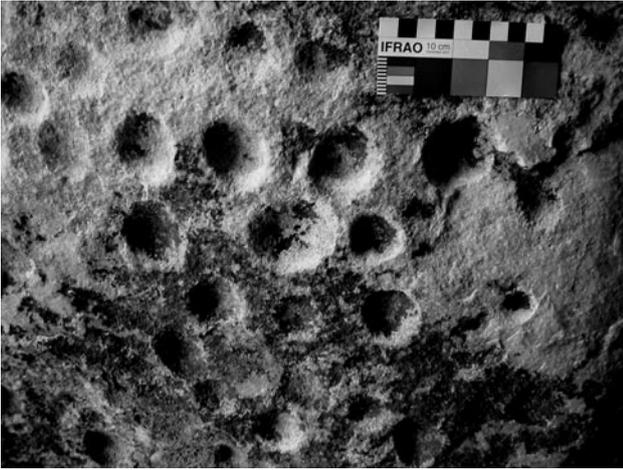


Figure 6. Some of the 540 cupules in the cave Daraki-Chattan, central India, of the Lower Palaeolithic.

is not common ethnographically and perhaps unlikely for the Lower Palaeolithic. The likelihood that these pigments were used for symboling activities (body painting, pretend menstrual blood, colouring of artefacts, colouring of rock surfaces) is much greater (consider the ethnography of the Tasmanians, the only observed society of Middle Palaeolithic technology). Nevertheless, in proposing symboling we are on safer ground with intentional engravings, be they on portable objects such as those of bone, ivory or stone, or in the form of petroglyphs on rock.

Concerning the latter, the most outstanding candidates are cupules — hemispherical depressions hammered into sometimes very hard rock surfaces, usually in groups, sometimes occurring in huge numbers (Bednarik 2008a). This archaic form of rock art is found in all continents except Antarctica, accounting in each of them for the oldest known kind of rock art but also occurring in numerous more recent cultural traditions. The oldest examples currently known date from the Lower Palaeolithic (Bednarik 1993; Bednarik et al. 2005). They occur in a few Indian quartzite caves, notably Auditorium Cave and Daraki-Chattan (Fig. 6). However, there is a good possibility that similar material in South Africa might be of a similar antiquity (Bednarik 2003a). The domination of very early rock art by these cupules is very probably a taphonomic phenomenon, therefore it tells us not very much about these palaeoart traditions or their range of expressions. Nevertheless, they are important to the origins of symboling because there can be no question about either their intentionality or their semiotic status. Their manufacture was highly labour intensive and they have no conceivable utilitarian function whatsoever.

Not so free of controversy is the issue of the portable non-iconic engravings found in many pre-Upper Palaeolithic contexts. The ‘short-range’ protagonists have consistently sought to reject individual finds by questioning the intentionality of engraved grooves, or by repudiating that they had been made with stone tools. In a number of cases their scepticism was indeed justified, but the tendency of extrapolating from these instances stifled the study

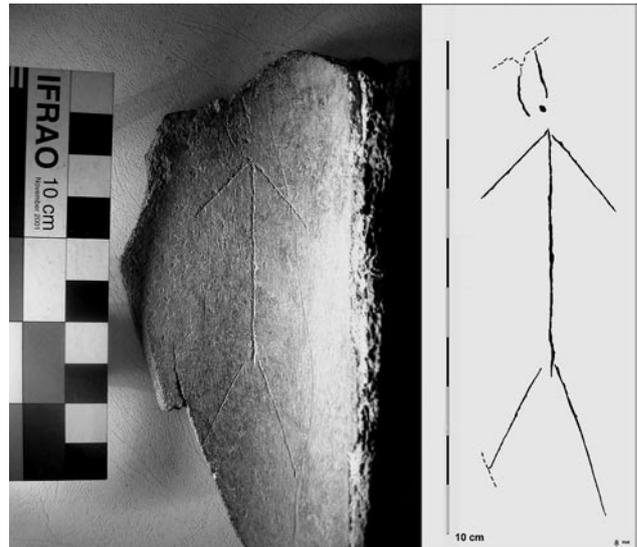


Figure 7. Apparently iconographic engraving on bone, Micoquian, Oldisleben 1, Germany.

of symbol origins greatly. The three main objections were that, among the many examples of pre-Upper Palaeolithic engravings, there were no recognisable motif templates; that there were no repeated patterns; and that far more examples were required to demonstrate semiotic intent. The first objections have been refuted at just a few sites, such as Oldisleben 1, Bilzingsleben and Blombos Cave. The first locality, a site of the Eem geological period north of Weimar, Germany, belongs to the eastern Micoquian. Together with a distinctive stone tool tradition thought to date broadly from between 135 000 and 80 000 years ago, three engraved bone fragments were recovered (Bednarik 2006). Two of them bear series of sub-parallel grooves made with such precision and under such conditions that their intentionality cannot realistically be questioned. The third, on the fragment of a shoulder blade, bears the engraving of an iconographic image (Fig. 7). This is the oldest picture found so far, and it destroys yet another cornerstone of the archaeological dogma, according to which iconic graphic art older than 40 000 years would never be found. The third objection, that only frequent use of symbols demonstrates symbol use, was always hackneyed, and it is dispatched by Donald’s (1991) proposition that all cultural information stored in objects external to the brain is symbolic and implies essentially ‘modern’ cognitive faculties. The traditional model of the origins of cognition and palaeoart is therefore refuted and Pleistocene archaeology is ready for a paradigm shift. Conversely, Donald’s model of an external, surrogate ‘cortex’ was actually not an original idea, it was foreshadowed by R. L. Gregory a couple of decades earlier. Gregory (1970: 148) suggested a circumvention of the need for continued brain growth by holding information in a more reliably stable and relatively permanent form, but Donald developed the idea further.

Neurophysiology

I have for decades and in numerous publications propounded the notion that the earliest known engravings, such as those from Bilzingsleben (Mania and Mania 1988), may provide valuable insights about the structure of the visual system as well as the origins of art-like productions. This position has recently been amplified and validated by various developments, especially the work of Derek Hodgson. Another proposition by me, that Palaeolithic artists had a strong neurophysiological predisposition to depict animals, especially salient aspects of their outlines, has also been decisively corroborated and elaborated by Hodgson (2003) and Hodgson and Helvenston (2006). This is because visual misinterpretation would have favoured objects that dominated the visual system of hominins, namely those that provoked the greatest desire or fear (especially large animals that presented either severe threats, or offered the prestige derived from slaying them for sustenance; Bednarik 1986, 1988, 1990c). Here, only a very brief summary of these and related matters can be given.

The human perception of contour and edge is a predetermined capacity of the visual system, which ‘encourages’ the detection of critical and specific stimuli in the object world (Alcock 1998: 173). Although the neurophysiological explanation of perception remains in flux, there is a good deal of evidence for a hierarchical scenario of progressively complex feature extraction culminating in modules for object identification (Logothetis and Sheinberg 1996; Tanaka 1996). It appears that the visual system limits the number of possible matches by processing incoming visual information at the lower level, in areas V1 through to V4 of the visual cortex, before categorising at the higher level (Lowe 1987).

There is a good reason why our visual system finds repeated marks such as parallel lines, geometric shapes and certain patterns appealing. It is because they resonate with patterns already integral to the visual cortex, they are related to the way its neurons process visual input. Artistic ‘primitive’ motifs are of interest to us not because they reflect properties of the external world, but because they simulate properties of the visual system (Bednarik 1984 *et passim*). For instance, the repetition of a simple line would have been evoking that part of the visual cortex that had allowed humans to see the continuity and pattern in the world at large (Hodgson 2000: 8). Most visual information processed by the visual cortex passes through the striate cortex (area V1 or Brodman’s Area 17). It is the largest known visual cortex area, perhaps even the largest cortical area. Cells in the striate cortex are ‘organised to respond to specific orientation of line and perception may be fabricated from the accretion of selected features’ (Hodgson 2000; *cf.* Hubel and Wiesel 1979; Tootell *et al.* 1998). It is thought that features are detected by cortical cells forming the bottom layer of a hierarchy of cells that respond progressively to increasingly abstract geometric features (Barlow 1972). Hodgson deduces that cells in higher layers could respond to simple geometrical patterns. A visual channel known as the magno system is concerned with decisions concerning which visual elements, including discontinuities and

edges, belong to specific objects in a scene (Livingstone and Hubel 1995). Significantly, Gestalt theory predicts that discrete elements are deemed more likely to form parts of a set if they show similar orientation or occur next to one another, than those oriented dissimilarly or spaced well apart (Bruce and Green 1990). One would expect these various principles of perceptual organisation to be reflected in the earliest engraved marks, and that is precisely what we do find in the engravings of the Lower and Middle Palaeolithic periods (Bednarik 1984, 1988, 1992, 1995, 2003a; Bednarik *et al.* 2005). These consist initially of parallel sets of straight lines (vertical or oblique), sets of convergent lines and dot patterns (cupules), *i.e.* repetitious elements. I have long emphasised the importance of reactions to edges and surface configurations, also evident in the graphic work of infants, chimpanzees and early hominins. The first structured engravings are followed by increasingly complex geometric arrangements, such as multiple arcs, zigzags, circles and radiate patterns.

This range of motifs brings us to another line of reasoning, which concerns the possible role of phosphenes in the earliest engravings (Bednarik 1984, 1990c *et passim*). After discovering that all pre-figurative engravings known in 1980 appeared to resemble phosphene motifs, not only at the phylogenic but also at the ontogenic level, I proposed the hypothesis that the production of art-like markings commenced with such motifs, both in the modern individual and in the species as a whole. All drawings produced by infants up to the appearance of iconicity in their work (at about four years of age) have been noted to consist of a limited repertoire of phosphene motifs (Kellogg *et al.* 1965). I found that precisely the same applies to all motifs prior to the appearance of pre-Historic figurative depiction, the advent of which was at that time placed around the Aurignacian 2 (more recent discoveries have changed this, especially my find of a Micoquian figurative engraving). Importantly, this hypothesis does not explain how phosphenes are connected to palaeoart origins, but it has never been falsified. All recent discoveries of the last twenty-eight years have squarely confirmed my phosphene hypothesis, and no competing theory has stood the test of time (especially the shamanic hypothesis of art origins, which is so inexpedient I will not bother to discuss it here).

The reason for the relevance of the phosphene hypothesis is it reinforces the notion that the earliest engravings we have reflect the operation of the visual system (Eichmeier and Höfer 1974). Phosphenes are most easily described as a kind of test pattern of the visual system. They are an autogeneous and involuntary phenomenon of the mammalian visual system whose form constants cannot be influenced by cultural conditioning and which seem to be ontogenically stable. This phenomenon can be produced by many factors, such as electrical stimulation (frequency dependent), pressure on the eyeball, blows to the head (‘seeing stars’), certain hallucinogens and many others. Phosphene forms are the fifteen known standard form constants of phosphenes, and most of these are found in the earliest engravings and petroglyphs. It is beyond doubt that phosphenes are intrinsic phenomena of the visual system, or

entoptic phenomena, and that they reflect inherent structures of the visual system rather than any external factor or information. Since the earliest graphic production of the modern infant and the earliest production of hominins both consist entirely of compositions resembling phosphene forms, I consider it likely that these art forms are in some way related to specific basic neural processes of the visual system. Therefore the idea that these earliest engravings ‘resonate’ with the neuron structures of the brain seems to be confirmed by the phosphene theory, according to which the entoptic stimulation recorded by the visual centre resembles inherent structures, such as perhaps that of the striate cortex.

Until such time as early graphic palaeoart is discovered that seems to contradict the phosphene hypothesis, it is the best lead we have in the search for the origins of art. Bearing in mind that we now have a substantial number of early graphic productions pre-dating the introduction of figurative graphic art, all of which support the proposition, the hypothesis has remained supremely unrefuted. Since the essence of science is the positing and testing of falsifiable propositions, this hypothesis is also the most scientific we have to account for the advent of art-like products. Competing hypotheses, on the other hand, are generally untestable, which raises again the spectre of the epistemology of traditional, orthodox Pleistocene archaeology. It tends to prefer unfalsifiable hypotheses to falsifiable ones; it is an unscientific process. That is perhaps the main reason why it arrives in most cases at false or flawed models, as can be demonstrated in many ways (see below).

A crucial contributing factor in creating the conditions for cognitive development must be the feedback relationship between a hominin and his environment: as he changes it and perceives the results of his actions, his awareness contributes to creating the basis of consciousness, establishing the potential for dialectic. The most obvious potential was in the area of visual stimuli. Having acquired a high degree of tactile proficiency during eons of tool making and tool use, the production of simple marks — possibly ‘discovered’ through the rhythmic manipulation of tools — would have resulted in a permanent, visually perceptible pattern which could be duplicated, examined and contemplated. Such marking behaviour would have a potential for expanding conceptualisation and the attendant proliferation of mental constructs, and the establishment of new mental structures.

Summary

Symbolling did not commence with the advent of the Upper Palaeolithic in Europe, but at least twenty times as long ago. Even the traditional sequence of emerging symbolic capabilities is to be discarded. Apart from the need to become much more circumspect in our pronouncements about this sequence, nothing seems quite as straightforward as a simplistic Darwinist model of gradually increasing complexity would predict. What we can say with some level of credibility is that precursors of symbol use that helped to prime the neural system of hominins did so already more than a million years ago. Biologically this is

unavoidable. A number of developments occurred perhaps a million years ago or soon after, which implies that symbolic systems began to have a significant impact on the lives of hominins. They led to profound cognitive and social changes permitting colonisation across sea barriers, and to other forms of domesticating natural systems. These included fire use, probably modification of domestic environments by shelter construction, and no doubt first use of clothing by a tropical primate colonising temperate and eventually even cold regions. It is during the final Early Pleistocene and the first part of the Middle Pleistocene that hominins can be shown to have started to collect rock crystals and fossils, and used red pigments. Most certainly, by that time, around 900 000 or 800 000 years ago, language-like communication was used effectively. A few hundred thousand years later, symbolic objects began to be modified. Proto-figurines and engraved plaques appear, as well as beads and pendants. Markings were now produced on various types of surfaces, including on rock, and a very few of them managed to survive to the present, under particularly fortunate preservation conditions. At this stage, still in the Lower Palaeolithic, we have to expect a kind of culturally differentiated society about as complex as some of those observed ethnographically. But this is still long before *Homo sapiens sapiens* emerged, it is still during the reign of the archaic *sapiens* hominins, whose perhaps most extreme form were the Neanderthals. By the advent of the Upper Palaeolithic, a mere 40 000 or so years ago, still in the reign of the Neanderthals, cognitive development was essentially complete. The complexity of symbolling, social systems and cognitive faculties was essentially identical to that available to modern society. By the late Aurignacian, Post-Neanderthals probably wove textiles and created master paintings we stand in awe of.

This is the kind of scenario we need to consider if we seek to find the origins of symbolling. On the basis of current evidence, the most crucial period, the time when hominins commenced a trajectory delivering them to where they are today, was the late part of the Early Pleistocene. By the time of its end, 780 000 years ago, the course had been set for our species, at least in terms of its fundamentals. More cannot be said at this stage, because the conditions for making more confident pronouncements simply do not exist. They are lacking because archaeology, in looking for these developments, has completely failed to come to terms with its errors, having looked essentially in the wrong places, and in the wrong era of human history.

To be more specific, *practically all major assumptions about the Pleistocene palaeoart of Europe appear to be false*. Franco-Cantabrian cave art is not a form of rock art endemic to caves; its exclusive occurrence in deep limestone caves is almost certainly a taphonomic phenomenon (Bednarik 1986, 1994b). It is not an ‘art’ created by shamans or great artists, much or most of it appears to be the work of teenagers (Bednarik 1986, 1990c, 2008b; Guthrie 2005; Sharpe and Van Gelder 2006). Metrical evidence shows unambiguously that the finger flutings in European as well Australian caves are largely, and often exclusively, of children, sometimes even of small infants. More deci-

sively still is the data derived from hand stencils: of those of thirty Palaeolithic caves of western Europe, 92.5% are by children under the age of seventeen, and not a single one is by a person over the age of twenty (Guthrie 2005). There is one more secure index of the age of the cave visitors: imprints of human body parts on soft cave floors and walls. Again the hard evidence is perfectly clear: the sample available today comprises the foot, heel, finger or handprints of no fewer than eleven caves (e.g. Clottes 1986, 1997: 31; Clottes and Courtin 1995: 175; Roveland 2000). Although many of the tracks are rather faint and not well suited for metric determination, it is amply evident that the overwhelming majority, certainly over 90%, derive from children or teenagers, and very few can be attributed to adults. Similarly, the only form of mobiliary art allowing the determination of approximate age of the artist is paint that has been applied with fingertips on plaques in the form of dots. Again, the empirical evidence shows conclusively that this dot art was made by juveniles (Bednarik 2002). In short, all types of Palaeolithic palaeoart permitting clear estimates of the artists' ages show that they were juveniles. Science operates by refutation of hypotheses; the proposition that a significant part of the 'art' is the work of young people has support, and there is no empirical evidence that a significant part of it is the work of adults.

Moreover, new evidence indicates that among extant traditions using exclusively non-figurative graphic art, children may be capable of producing perfect figurative images when prompted (Sreenathan et al. 2008). This could then be seen as a 'juvenile' form of expression, and it should have always been obvious that figurative imagery is cognitively less developed than non-figurative. Whereas in figurative symbolism, the connection between referent and referrer is purely via iconicity — a relatively simple cognitive factor building on visual ambiguity and accessible even to animals other than humans — the symbolism of non-iconic art is only navigable by possessing the relevant cultural 'software'. Figurative art results from a deliberate creation of visual ambiguity (Bednarik 2003a: 408, 412) and is therefore based on lower levels of perception and neural disambiguation than non-figurative art.

If one adds to these considerations the orthodox views that European Palaeolithic cave art consists mainly of zoomorphs (it does not; most of it is nonfigurative); or that zoomorphs mark Pleistocene art (less than 1% of the world's surviving Ice Age palaeoart is figurative); or that all Pleistocene rock art is of the Upper Palaeolithic (in fact it is greatly outnumbered by Middle Palaeolithic rock art), one begins to appreciate the depth of the issue. Practically all widely held beliefs about Pleistocene palaeoart are either false, or are very probably false.

The abilities of creating arbitrary relationships between referrer and referent and of creating external storage of cultural information are among the most defining characteristics of late humans. Pleistocene archaeology has consistently ignored this, has focused largely on its invented tool categories, and has thus failed to provide a cultural synthesis of human evolution. It has therefore fundamentally failed in the task it set itself. Symbols are the most

powerful driving force that made humans human. They are abstract, often society-specific constructs of reality aspects. Especially those detectable visually are physical fragments of human interpretation of the physical world. Their full meanings are only interpretable within the social contexts that created them, even in the case of iconographic symbols — but most especially in those that lack iconographic anchor points. The proper study of this vast body of evidence, called palaeoart, has not yet begun. What we have seen so far is embryonic and inadequate, especially when it is compared with the enormous progress we have made in other disciplines. Perhaps proper study of this important field will begin in the present century. And perhaps it will, some time, lead to an understanding of how humans created their realities out of chaos.

REFERENCES

- ALCOCK, J. 1998. *Animal behavior — an evolutionary approach*. Sinauer Associates, Sunderland, Mass.
- AIELLO, L. C. and P. WHEELER 1995. The expensive-tissue hypothesis: the brain and the digestive system in human and primate evolution. *Current Anthropology* 36: 199–221.
- BARLOW, H. B. 1972. Single units and sensation: a neurone doctrine for perceptual psychology? *Perception* 1: 371–394.
- BEDNARIK, R. G. 1984. On the nature of psychograms. *The Artefact* 8: 27–33.
- BEDNARIK, R. G. 1986. Parietal finger markings in Europe and Australia. *Rock Art Research* 3: 30–61, 159–170.
- BEDNARIK, R. G. 1988. Comment on D. Mania and U. Mania, 'Deliberate engravings on bone artefacts of *Homo erectus*'. *Rock Art Research* 5: 96–100.
- Bednarik, R. G. 1990a. On the cognitive development of hominids. *Man and Environment* 15(2): 1–7.
- BEDNARIK, R. G. 1990b. An Acheulian haematite pebble with striations. *Rock Art Research* 7: 75.
- BEDNARIK, R. G. 1990c. On neuropsychology and shamanism in rock art. *Current Anthropology* 31: 77–80.
- BEDNARIK, R. G. 1992. Palaeoart and archaeological myths. *Cambridge Archaeological Journal* 2: 27–43.
- BEDNARIK, R. G. 1993b. Palaeolithic art in India. *Man and Environment* 18(2): 33–40.
- BEDNARIK, R. G. 1994a. Art origins. *Anthropos* 89: 169–180.
- BEDNARIK, R. G. 1994b. A taphonomy of palaeoart. *Antiquity* 68: 68–74.
- BEDNARIK, R. G. 1995. Concept-mediated marking in the Lower Palaeolithic. *Current Anthropology* 36: 605–634.
- BEDNARIK, R. G. 1998b. The 'australopithecine' cobble from Makapansgat, South Africa. *South African Archaeological Bulletin* 53: 4–8.
- BEDNARIK, R. G. 1999a. Pleistocene seafaring in the Mediterranean. *Anthropologie* 37(3): 275–282.
- BEDNARIK, R. G. 1999b. Maritime navigation in the Lower and Middle Palaeolithic. *Comptes Rendus de l'Académie des Sciences Paris, Earth and Planetary Sciences* 328: 559–563.
- BEDNARIK, R. G. 2001. Beads and pendants of the Pleistocene. *Anthropos* 96: 545–555.
- BEDNARIK, R. G. 2002. An Acheulian manuport from Morocco. *Rock Art Research* 19: 137–139.
- BEDNARIK, R. G. 2003a. The earliest evidence of palaeoart. *Rock Art Research* 20: 89–135.
- BEDNARIK, R. G. 2003b. Seafaring in the Pleistocene. *Cambridge Archaeological Journal* 13: 41–66.

- BEDNARIK, R. G. 2003c. A figurine from the African Acheulian. *Current Anthropology* 44(3): 405–413.
- BEDNARIK, R. G. 2006. The Middle Palaeolithic engravings from Oldisleben, Germany. *Anthropologie* 44(2): 113–121.
- BEDNARIK, R. G. 2008a. Cupules. *Rock Art Research* 25: 61–100.
- BEDNARIK, R. G. 2008b. Children as Pleistocene artists. *Rock Art Research* 25 (in press, November issue).
- BEDNARIK, R. G., G. KUMAR, A. WATCHMAN and R. G. ROBERTS 2005. Preliminary results of the EIP Project. *Rock Art Research* 22: 147–197.
- BIESELE, M. 1993. *Women like meat: the folklore and foraging ideology of the Kalahari Ju/'hoan*. Indiana University Press, Bloomington (IN).
- BRUCE, V. and P. R. CREEN 1990. *Visual perception: physiology, psychology and ecology*. Lawrence Erlbaum Associates, Hove and London.
- CABE, P. A. 1980. Picture perception in nonhuman subjects. In M. A. Hagen (ed.), *The perception of pictures* (Vol. II), pp. 305–343. Academic Press, New York.
- CALDWELL, D. 2008. Are Neanderthal portraits wrong? Neanderthal adaptations to cold and their impact on Palaeolithic populations. *Rock Art Research* 25: 101–116.
- CLOTTE, J. 1986. Comment on R. G. Bednarik, 'Parietal finger markings in Europe and Australia'. *Rock Art Research* 3: 160–161.
- CLOTTE, J. 1997. *Niaux. Die altsteinzeitlichen Bilderhöhlen in der Ariège*. Jan Thorbecke Verlag, Sigmaringen (transl. French edn 1995).
- CLOTTE, J. and J. COURTIN 1995. *La grotte Cosquer: peintures et gravures de la caverne engloutie*. Seuil, Paris.
- COSS, R. G. 1985. Evolutionary restraints on learning: phylogenetic and synaptic interpretations. In N. M. Weinberger, J. L. McGaugh and G. Lynch (eds), *Memory systems of the brain — animal and human cognitive processes*, pp. 253–273. The Guilford Press, New York.
- DAWKINS, R. 1991. *The blind watchmaker*. Penguin, London.
- DEACON, T. 1997. *The symbolic species*. Penguin, Harmondsworth.
- DE BEER, G. 1940. *Embryos and ancestors*. Oxford University Press, Oxford.
- DONALD, M. 1991. *Origins of the modern mind: three stages in the evolution of culture and cognition*. Harvard University Press, Cambridge, MA.
- EICHMEIER J. and O. HÖFER (ed.) 1974. *Endogene Bildmuster*. Urban and Schwarzenberg, Munich.
- FELIKS, J. 1998. The impact of fossils on the development of visual representation. *Rock Art Research* 15: 109–134.
- FIEDLER, L. 2003. Was ist Paläo-Kunst? *Rock Art Research* 20: 114–115.
- GOREN-INBAR, N. 1986. A figurine from the Acheulian site of Berekhat Ram. *Mi'Tekufat Ha'Even* 19: 7–12.
- GREGORY, R. L. 1970. *The intelligent eye*. Weidenfeld and Nicolson, London.
- GUTHRIE, R. 2005. *The nature of Paleolithic art*. The University of Chicago Press, Chicago/London.
- HODGSON, D. 2000. Art, perception and information processing: an evolutionary perspective. *Rock Art Research* 17: 3–34.
- HODGSON, D. 2003. The biological foundations of Upper Palaeolithic art: stimulus, percept and representational imperatives. *Rock Art Research* 20: 3–22.
- HODGSON, D. and P. A. HELVENSTON 2006. The emergence of the representation of animals in palaeoart: insights from evolution and the cognitive, limbic and visual systems in the human brain. *Rock Art Research* 23: 3–40.
- HOVERS, E., O. BAR-YOSEF and B. VANDERMEERSCH 2003. An early case of color symbolism — ochre use by modern humans in Qafzeh Cave. *Current Anthropology* 44: 491–522.
- HUBEL, D. H. and T. N. WIESAL 1979. Brain mechanisms of vision. In *Readings from Scientific American. Mind and behaviour*, pp. 32–44. Freeman, San Francisco.
- KELLOGG, R., M. KNOLL and J. KUGLER 1965. Form similarity between phosphenes of adults and pre-school children's scribbles. *Nature* 208: 1129–1130.
- LEONARD, W. R. and M. L. ROBERTSON 1994. Evolutionary perspectives on human nutrition: the influence of brain and body size on diet and metabolism. *American Journal of Human Biology* 6: 77–88.
- LEONARD, W. R. and M. L. ROBERTSON 1996. On diet, energy metabolism, and brain size in human evolution. *Current Anthropology* 37: 125–129.
- LIVINGSTONE, M. S. and D. HUBEL 1995. Through the eyes of monkeys and men. In R. L. Gregory, et al. (eds), *The artful eye*, pp. 52–65. Oxford University Press, Oxford.
- LOGOTHETIS, N. K. and D. L. SHEINBERG 1996. Visual object recognition. *Annual Review of Neuroscience* 19: 577–621.
- LOWE, D. 1987. Three-dimensional object recognition from single two-dimensional images. *Artificial Intelligence* 31: 355–395.
- PINKER, S. 1997. *How the mind works*. Penguin, Harmondsworth.
- ROVELAND, B. 2000. Footprints in the clay: Upper Paleolithic children in ritual and secular contexts. In J. Sofaer Derevenski (ed.), *Children and material culture*, pp. 29–38. Routledge, London.
- SHARPE, K. and L. VAN GELDER 2006. Finger flutings in Chamber A1 of Rouffignac Cave, France. *Rock Art Research* 23: 179–198.
- SREENATHAN, M., V. R. RAO and R. G. BEDNARIK 2008. Palaeolithic cognitive inheritance in aesthetic behavior of the Jarawas of the Andaman Islands. *Anthropos* 103 (in press).
- TANAKA, K. 1996. Inferotemporal cortex and object vision. *Annual Review of Neuroscience* 19: 109–139.
- TOOTELL, R. B. H., K. HADJIKHANI, W. VANDUFFEL, A. K. LIU, J. D. MENDOLA, M. I. SERENO and A. M. DALE 1998. Functional analysis of primary visual cortex (V1) in humans. *Proceedings of the National Academy of Sciences of the U.S.A.* 95: 811–817.

AURA Newsletter

Editor: Robert G. Bednarik

Editorial address: AURA, P.O. Box 216, Caulfield South, Victoria 3162, Australia

Tel./Fax No.: (613) 9523 0549

E-mail: auraweb@hotmail.com

© This publication is copyright. Published by Archaeological Publications, Melbourne.