The Longest Transition or Multiple Revolutions?

Curves and Steps in the Record of Human Origins

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Abstract Preservation and the history of archaeology have led to classification of a Stone Age in stone, in which there are naturally phases and transitions. A major issue is whether the phases have an overriding reality, and whether they give a good fit between biological and cultural evolution. In the evidence of biological evolution there is a surprisingly smooth curve documenting the rise in brain size through the Pleistocene. Models of social competition and the managing requirements of a 'social brain' have claims to explain much of the change without reference to archaeological phasing. In contrast the cultural scheme has to take into account detailed variation in artefacts (e.g., 'traditions' including the Oldowan and the Acheulean; and their polythetic aspects of presence and absence; that Acheulean hand-axes run on into later periods, and then changes in functional solutions, such as hafting). The other major biological scheme, that of hominid palaeontology, presents other complications as there is not full agreement over speciation issues such as chronospecies and anagenesis. To add to all this, recovery of genomes indicates that selection in large numbers of individual genes occurs through the same time. Transitions as we see them in a single discipline may thus be artefacts of the nature of the proxy; in sets of disciplines they may be reinforced or undermined by coincidental factors. Their significance may be unintentionally enhanced by our focus on them, and our tendency to ascribe a reality to entities simply because they have been named. Here a multidisciplinary approach is advocated as necessary to isolate real major changes in human capabilities. Concentrating on the total number of cultural traits available for study, the paper concludes with the view that a first human revolution had been achieved by about 1.6 million years, that a second revolution, largely silent archaeologically, had occurred by about 500,000; that a third revolution, of modernity, occurred thereafter. These are aspects within the dominating continuity of an evolutionary trend into a cognitive niche.

Introduction

This paper takes its rationale from a major contrast: in archaeology we often see a record of steps, and phases; but through the Pleistocene, from the time of the earliest technology, there has been one surprisingly smooth curve of change in brain size. It is even possible that most developments can be explained through a single feedback model. If that were so, would our phases and transitions simply be artificial impositions, or would they still embody important realities?

Traditionally, archaeologists have been able to divide up the past to their convenience. Now we are living with several competing views of the past. Each of them gives us a different proxy, but in the end they must be reconcilable. Classifications of hominid palaeontology give us one view, with several species in sequence or side by side—how do the steps fit with archaeology? Brain size, already

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mentioned, can be related to the 'social brain' in another scenario. Last, but evidently not least, the mapping of genomes is providing new evidence for positive selection of particular genes (Krause et al. 2007; Hill and Walsh 2005; Nielsen et al. 2005). They will eventually be fitted to the timescale, generating further charts with steps and transitions.

In archaeology successions of periods seem to be a structural necessity, and so inevitably we have transitions. The same might be said for history, but history operates on a different basis. If a dynasty falls, it is evident that a regime has ended, but equally that the dynamic of everything else tends to go on—the change may be superficial, or can become profound. In early archaeology, periodisation starts simply from bodies of artefacts that are static and any change (rather than no change) can lead us to think that steeper periods of transition—which might require special explanation—separate long periods of stasis. Although the new thing may not be of great significance, it may be coerced to serve as proxy for other suspected changes. More general social approaches need to transcend such disciplinary peculiarities to give broad perspectives, so it is important that archaeological classifications should reflect real and significant changes in the record (Bogucki 1999; Dunbar 2004; Megarry 1995; Runciman 2000).

My paper aims to evaluate such changes—including those leading up to modern humans—in a broader evolutionary perspective, influenced by the alternative approaches mentioned. After critical examination of these viewpoints, I attempt another approach to behavioural evidence, using larger numbers of traits.

The Archaeological View

In the frame of hominid evolution Archaeology begins formally with tool-making that can leave a record, and in general schemes it has dealt with Early, Middle, and Later stone ages in Africa, and Lower, Middle, and Upper Palaeolithic in Europe and much of Asia (all much debated: e.g., Allchin 1963; Bishop and Clark 1967). Although in the 1960s there was a move to abandon the tripartite divisions in favour of purely culture-stratigraphic sequences, it is interesting to see that the main framework survived. Indeed discrepancies between the European and African schemes have been gradually eased out, and fortunately improved dating has removed some of the apparent offsets. Broadly we can now talk of an Early Palaeolithic from 2.6 to 0.4 million years, a Middle Palaeolithic from 400,000 to 40,000 years, and a Late Palaeolithic from 40,000, in which the classic 'Upper Palaeolithic' is one regional variant (e.g., Conard 2005; Henshilwood and Marean 2003; McBrearty and Brooks 2000; Mellars 2005; cf Barkai et al. 2003 for evidence of earliest Middle Palaeolithic at Qesem Cave). Yet most archaeologists are also aware of an arbitrariness in such schemes, as shown in these discussions.

What is going on? At the simplest level, it could be that modern humans have a firm tendency to classify initially into phases of beginning, middle, and end. If we do that to 2.5 million years of Stone Age, then inevitably there will major steps between the phases. Our next step might be to smooth things, simply because we are uncomfortable with the steppiness. Arguably, this was done in the African Stone Age, through the creation of 'Intermediate' phases between ESA and MSA, and between MSA and LSA. Archaeologists soon became uncomfortable with the effects because of their evident discrepancy from reality, and in practice they soon reverted to simpler if imperfect schemes (see Recommendations in Bishop and Clark 1967, 879–901).

Another thing might well happen: initially arbitrary period divisions might migrate to the most significant change-points in the time spectrum, tuned by the search for real difference. Good dating would be prerequisite for that. The recent convergence of Early-Middle-Late Palaeolithic timelines in different parts of the Old World has little theoretical basis, but may well testify to rapid take-up of fundamental technological innovations. Certainly, the actual records appear more similar from area to area than was thought in an era of distorted dating.

The most important point to carry forward is that through the bulk of the Pleistocene, the major changes do indeed seem technical, based on new ideas rather than evidence of a cultural identity. That may be true for a change as important as the Oldowan-Acheulean transition (Gowlett 1986; Toth and Schick 2004).

Hominid and Hominin Species

Do changes in species reflect such archaeological events? There is reasonably good consensus that the genus *Homo* appeared around 2.5–2.3 Ma (Kimbel et al. 1996); that *Homo erectus* appeared around 1.8–1.6 Ma; that more modern hominins began to appear around 0.5 Ma, leading to the Neanderthals and to modern humans (see e.g., Aiello 1993; Bräuer 1992; Rightmire 1990, 1998, 2004; Wood and Collard 1999). There is less agreement about modes of speciation ('punctuated equilibrium,' chronospecies, anagenesis) or the number of species names necessary in different parts of the world—for example, whether *Homo heidelbergensis* is simply a European Neanderthal ancestor, or whether it is also the best label for African hominins that lead to modern humans within Africa (as seen by Rightmire 1998; cf Bräuer 1992; Stringer 2003). There is not consensus, but it may be possible to see an 'end' to *Homo erectus* around 500,000, except perhaps in the Far East (cf Chen et al. 1994; Rightmire 2004).

It is, however, almost impossible to map stone tool traditions closely to particular species (*pace* Foley 1987, although it does seem likely that regionally new populations sometimes brought new technologies). The Acheulean begins after *Homo erectus*, and certainly outlasts it. If we include the late Acheulean (as at Dakhla in Egypt, or in Syria; or the late cordiform bifaces of France or bout coupé hand-axes of Britain) within the 'true' Acheulean, then the tradition is also made by *heidelbergensis*, *sapiens* and *neanderthalensis* (Besançon et al. 1978; Mellars 2005; Schild and Wendorf 1977). That position is easiest to accommodate if we take the bifaces not as a signal of anything in particular, but simply to be a useful set of technical solutions, which tended to recur and recur until something distinctly better came along (as probably permitted by hafting). Some scholars see a problem in trans-species continuity, but just as the younger species must inherit DNA from their ancestors, so retention of some cultural traits in a cultural animal seems a necessity rather than a reasonable idea.

As with artefact classifications, one might expect classificatory delineations between species to migrate to the periods of fastest change. That expectation has seemed to be met in the case of the emergence of *Homo*, of *H. erectus*, and of

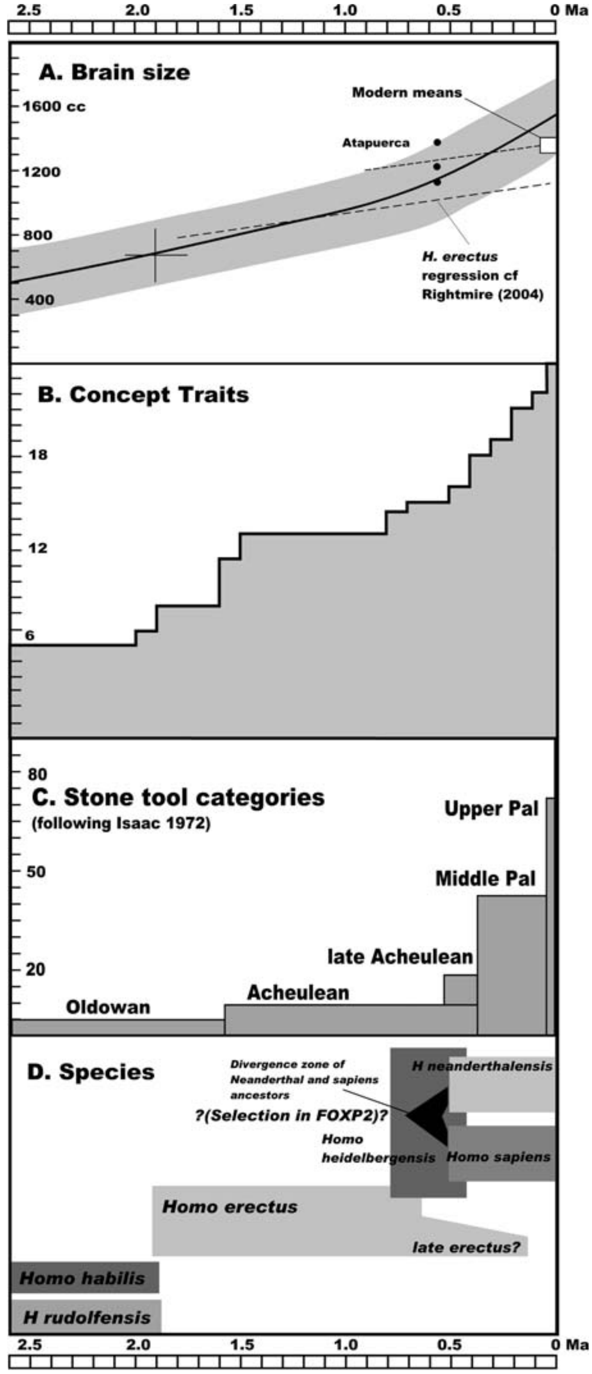

Fig. 1 Several lines of evidence in human evolution set on a common timescale. **A.** Curve of cranial capacity through the Pleistocene. Compiled with data from Lee and Wolpoff (2003), Rightmire (2004), Tobias (2005), Beals et al. (1984), Rushton (1994); the cross indicates mean 640 cc of 6 specimens of *Homo habilis* plotted by Tobias, superimposed on the general trend. **B.** Concept traits (see Fig. 2 for detailed explanation). **C.** Stone tool categories, modified after Isaac (1972). **D.** *Homo* species categorisation (*Homo ergaster* and *georgicus* are subsumed within early *Homo erectus*)

post-*erectus* species. But it also appears that these change points do not coincide closely with archaeology (Fig. 1). The old idea of an *erectus* stasis may retain some substance (see below), but it does not fit well with the Acheulean, which does not occur in all *erectus* areas, and long outlasts *erectus*.

The Brain Size Curve

The brain size curve is introduced here because, on the basis of evidence available in the early 1990s, it too appeared to have major steps (e.g., Aiello 1996).

There are complications, however: in hominoids brain size varies considerably between individuals. Total cortical area and efficiency of connections within the cortex may also be important factors (Reed and Jensen 1993; Hill and Walsh 2005). Cranial capacity is also affected by body size. The past record shows similar variation in earlier humans. Sampling is also poor. In this context it is all the more surprising that brain size now appears to increase steadily from 2.6 million years ago, in a curve which is astonishingly smooth. After five million years at ape size, it begins to increase 2.5–2.0 million years ago, becoming three times larger through the Pleistocene (Fig. 1).

Figure 1 portrays the general trend in a schematic way. To achieve statistical rigour would be very difficult without making many assumptions. The line is drawn to follow the trend of data in Lee and Wolpoff (2003) and takes into account Rightmire (2004), but emends some dates (e.g., Atapuerca Sima de los Huesos, taken as 0.2 Ma by Lee and Wolpoff, goes back to c. 0.5 Ma following Bischoff et al. 2003, 2007; Ngandong, seen as 0.25 Ma by Lee and Wolpoff, is taken as 0.04 by Rightmire, following Swisher et al. 1996).

Rightmire's regression is interesting, because it is fitted exclusively to *Homo erectus* specimens, excluding Dmanisi, but admitting Ngandong (former Solo) as a very late *erectus*. The effect is somewhat to flatten the line. Even so, Rightmire finds a steady cline through *erectus* from about 800 to 1100 cc. If that line is accepted, and 'joined' to earlier and later species' volumes, then that might reinforce the ideas of steps (or even grade change). Yet plotting all *Homo* specimens without references to the species interpretation makes the curve become far smoother. Through the last half-million years, there is commonly assumed to be another huge step up, perhaps associated in some way with 'modernity' (see e.g., Fig. 8.1 in Aiello [1996]). Again, the evidence for some major change of gear at this point is not compelling—once modern population means are taken into account. For example, the Atapuerca specimens from Sima de los Huesos, now dated to c. 500 ka (Bischoff et al. 2003, 2007) have volumes of 1390, 1125, and 1220 cc, respectively (Atapuerca 4, 5, 6). They would thus fit easily into modern populations which have overall means of c. 1420 cc for males and 1280 cc for females (standard deviations approximately +/–80) (Beals et al. 1984; Rushton 1994). (Controversies over regional differences have been tackled by Reed and Jensen [1993] and Lieberman [2001]: the only issue of interest here is the general evidence of modern human volumes).

The points to take forward are:

(1) The idea of sudden steps in the curve is suspect—they are likely to be created by sampling biases, including local geographic variation, and variable taphonomic considerations.
(2) The old supposed evolutionary stasis of *Homo erectus* is undermined by newer finds and dates. There may be a steep rise around 1.5 million years ago, partly owing to larger body size, but thereafter the evidence points to a steady rise in overall body size through a long period.
(3) The recent climb in volumes is far less steep than generally supposed.

The mechanisms for such a prolonged steady climb must result from a response to natural selection of a fairly extreme kind, given the great metabolic costs of supporting a larger brain (Aiello and Wheeler 1995; Lennie 2005). Over the years many explanations have been offered: technological ones might relate most closely to archaeological explanations, but they have seemed insufficient alongside social factors (Gamble 1998). After all, if humans were fairly successful across the Old World with limited technology and small brains—as sites such as Dmanisi demonstrate—why should such extreme change need to follow?

Social models place a strong claim to account for the change, and will be discussed in the interpretation below. Managing large numbers of relationships evidently requires a great deal of brain power (Aiello and Dunbar 1993; Aiello and Wheeler 1995; Dunbar 1993, 1998). In general, hunters and gatherers live in quite small groups. Within a band, an adult has to take into account perhaps ten other adults. It is impressive then that the human brain can take into account perhaps more than a hundred absent adults, but less evident that this should require intensive processing from minute to minute. The cost of cortical processing is high enough, however, to be a force restricting activity to a small part of the cortex at one time (Lennie 2005), casting some further light on past evolutionary pressures. Responses to these at technical and ecological levels were probably also cognitively demanding, emphasising a need for combined social-technical-competence models.

The immediate point is that step transitions are far less evident than commonly thought, suggesting a general continuity of pressures and responses, and the next question is whether genetic evidence can cast other light on this.

Genetics

Although genetics works back mainly from present day genomes, such as those of modern humans and the chimpanzee, the very rapid progress in recovering a Neanderthal genome suggests that some past *rates* of genetic change, and histories of positively selected genes, will become available (Green et al. 2006; Nielsen et al. 2005; Hill and Walsh 2005). They will tell a complex story: it seems plain already that changes in many (but not huge numbers) of different genes will be involved in creating a large brain, an enlarged birth canal, prolonged adolescence, changed sleep schedules, and many other evolutionary changes. Even if there were one major evolutionary driving force, many genes would be involved in response to it, probably with different timings.

The Neanderthal genome is especially important in establishing a comparative frame which allows a divergence point from ancestors of modern humans to be set in the past at c. 0.7–0.5 Ma (Green et al. 2006). That divergence (which probably stems from a parent population of *Homo heidelbergensis*) will enable some calibration of rates of change at particular loci. For example, the gene FOXP2, which plays a part in supporting language abilities, appeared to have been modified under strong selection within the last 200,000 years (Enard et al. 2002; Lai et al. 2001), but its presence in Neanderthals in the same derived form as in modern humans indicates a very strong likelihood that this derived form was already there in a common ancestor ~750,000 years ago (Krause et al. 2007). AHI1, involved in cortex axon pathfinding, and MCPH1, which encodes microcephalin, also appear to have been positively selected recently, probably within the Pleistocene (Hill and Walsh 2005). They are highlighted as evidence that such events have to be weighted into interdisciplinary charts.

The Rationale for a Multidimensional Approach

Most archaeologists have reservations about present classifications, but it is very hard to become free from them. A detailed classification in stone can be unhelpful and uninteresting to workers in other disciplines. We are constrained by their double purpose—on the one hand they give us convenient rule-of-thumb ways of dividing the past world into manageable segments. On the other, there is an ideal that they are supposed to represent something of the world as seen by its past inhabitants. Archaeologists have a duty to consider the latter alongside their own convenience (Camps 2004). In ‘Aurignacians’ or ‘Magdalenians’ or ‘Natufians’ there is still in some way a claim to recover past cultural identities, although it has long been appreciated that the Oldowan and Acheulean are entities on a vastly different scale (Clarke 1968; Isaac 1972, Fig. 7, 389).

What packages of features make up such an entity? Through the stone ages the features of distinction are often still ad hoc: thus the Oldowan, named after Olduvai (Leakey 1971), is characterised by the basic technical attributes of stone-working, not by positive stylistic features. The initial assumption was that the Oldowan was specific to Africa, but it would be hard to find a basis for excluding similar early industries in other parts of the world. The Acheulean is distinguished purely through the addition of the large cutting tools, or bifaces with a long axis. Bifaces, however, appear to have been tools with particular functions, made and used only where those functions were needed (site complexes such as Olorgesailie and sequences such as Notarchirico show equally the extent of variation and presence/absence: Isaac 1977; Potts et al. 1999; Piperno et al. 1998; Piperno and Tagliacozzo 2001; Villa 2001). David Clarke (1968) envisaged the *polythetic* entity, in which not all categories had to be present in any one occurrence. There is however a major difficulty inherent in any classification which actually depends on a single artefact category that can be locally absent for all kinds of reasons.

The position is not much easier when a phase is defined by multiple technical or typological characters. The Middle Palaeolithic is signalled through more standardised ways of making flakes, and more refined scrapers, points, and other tool 'types.' As all of these can occur in the later Acheulean (and bifaces are 'allowed' in the Middle Palaeolithic), it is not surprising that debate over the Lower/Middle Palaeolithic transition goes back a very long way (e.g., papers in Ronen 1982).

The essential problem is that conventional classification is looking for fixed criteria—either one firm signal, or two or three that hang together—in a frame of material culture that is actually a multivariate world, even from an early stage. Hence the difficulties of the 'Mode' system of Grahame Clark (1977), which has been criticised previously because it is unilinear in expression (Gowlett 1999; Villa 2001). Many industries combine Modes 1 and 2 characteristics, others certainly Modes 3, 4, and 5 (Clark himself noted that 'more often than not particular industries are seen to combine technique from more than one stage of development' [1977, 24]).

Concepts and Traits

On all these grounds, it seems desirable to seek more broadly based approaches, and to look at arrays of characteristics, or traits (e.g., Reynolds 1991; Rigaud 1989; Stringer and Gamble 1993). For these we would ideally have a better theoretical basis. Here the ***concept*** is emphasised: it is internal, but can be seen as an idea that is shaped by external experience (e.g., Lambon Ralph et al. 2001). The attribute or trait is external: material culture can however be seen as an external projection of internalised ideas. Its materialness seems to be more than a late human add-on to an older internalised ideational world. Focus on objects seems to be fundamental to the world of activity demonstrated by mirror neurons in the case of Old World monkey brains (Gallese et al. 1996, 2004), and offers the basis for jointly appreciated activities. In any event, the very essence of culture is shared ideas, but it is not easy to isolate individual concepts within the great mass of information which is somehow transmitted. There will be imprecision, yet the scheme can be reasonably robust through addressing a number of characteristics.

In this effort to generate another dimension for looking at transitions, I found it possible to assemble about 24 concepts applicable through the Palaeolithic, each of which is taken to represent a different or new idea (Fig. 2). For several of these concepts or traits there is considerable uncertainty either about the evidence or its chronology, so a doubt range is indicated for these. Then, to compile a general picture (Fig. 1) calculated at 0.1 Ma intervals, each concept/trait 'in doubt' was scored at 0.5 through the doubt range. This is at least a declared approach to roughing out a view of the evidence. As Isaac wrote with respect to artefact types: 'this diagram is deliberately contentious.... It certainly emphasizes the need for systematic study of the problems' (Isaac 1972, 394, Fig. 5). Very brief notes are offered below on the individual aspects.

In the case of stone tools, the criterion has been introduction of new major idea, such as 'imposing long axis'. I have tried to distinguish these from the simple proliferation of tool types, thus presenting separately (but not excluding) a related longstanding issue, the number of tool types. Isaac (1972) listed numbers of tool types as seen in conventional typologies (Fig. 1). If valid, each type would embrace constellations of concepts, many of them similar for each tool (as in 'appropriate length', 'appropriate breadth'). Thus the same or similar concepts would be repeated through 'multiplicity'. As an industry with 100 types has much more informational content than one with 10 types, making and managing them all exerts a greater cognitive

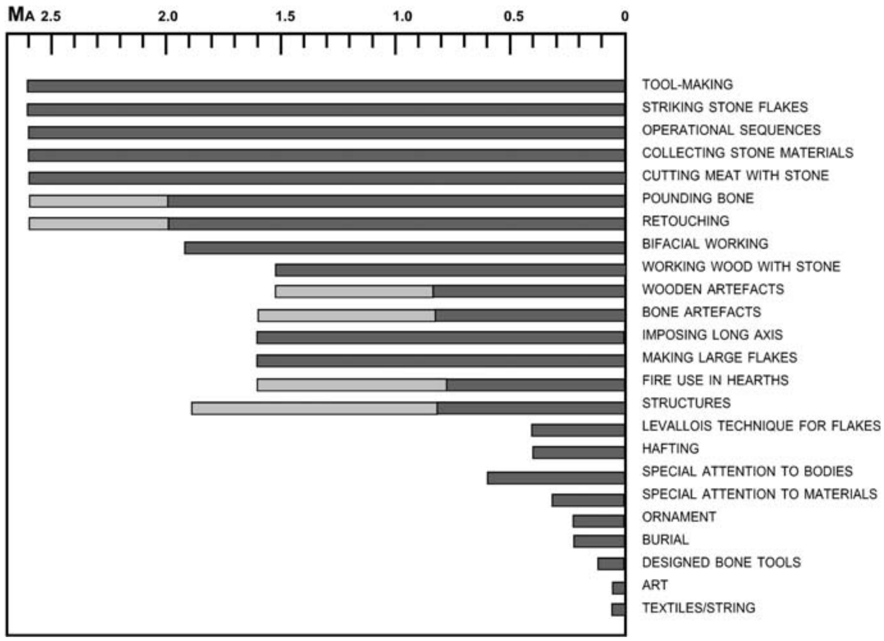

Fig. 2 The introduction of new concepts in material culture plotted through the Pleistocene. The open outlines show doubt ranges from the point of first (debated) appearance to the time of general acceptance. To provide a summary in Fig. 1, the total number of traits has been calculated at intervals of 0.1 Ma, with traits in debated range being scored as 0.5

load; the evidence is of interest. A single complex lithic (such as a biface) embraces a substantial number of different concepts, compared with a simple flake. The relations between these are of interest in studies of cognition (McPherron 2000, 2006; Gowlett 2006), but as they repeat similar content, they are not included in the list as new concepts. In the same way, the scheme as presented does not attempt to follow through greater stone transport distances (or infer territorial information), because the basic ideas do not necessarily change.

Levallois techniques, or specialised production routines for manufacture of flakes, do show a further concept and application. They are taken as appearing first around 400,000 years (e.g., Barkai et al. 2003; McBrearty and Brooks 2000), dates that also fit with the earliest signs of this technology in Europe (see also Rolland 1995). They may well be associated with hafting (see below).

In the case of wood, the earliest evidence comes from phytoliths adhering to bifaces at Peninj at c. 1.4 Ma (Domínguez-Rodrigo et al. 2001), and from microwear studies on stone artefacts of similar age at East Turkana (Keeley and Toth 1981). Far earlier use might well be expected, but there is no direct evidence. In the case of wooden artefacts, a polished plank from Gesher Benot Ya'aqov is taken as the earliest known (Belitzky et al. 1991), then there is little or no evidence until the spears at Schöningen (Thieme 1998, 1999, 2005). The earlier evidence of woodworking may well suggest that it was for tools, but that is not demonstrated (as a comparable example Thackeray et al. [2005] demonstrate use of stone for pounding bone in the Oldowan at Kromdraai, but that need not imply any use of bone for tools).

Schöningen is also important for the first evidence of hafting, in the form of short wooden staves grooved to allow insertion of a stone tool (Thieme 1998). There is no evidence for glue or twine, but the compound idea is quite definitely present. Cord or twine is directly attested in the eastern Gravettian (Soffer et al. 1998).

In the case of bone, an early large flaked piece comes from Olduvai Bed II, BK, alongside various other modified pieces (Leakey 1971, Fig. 114). Bone points believed to have been used at Swartkrans for digging would be of approximately the same age (Backwell and d'Errico 2005); thereafter, most evidence comes from the Middle Pleistocene, where bone bifaces are occasionally plentiful (e.g., Castel Guido west of Rome [Boschian and Radmilli 1999]). Artefacts made to a design specific to bone can be seen as a further concept, first appearing in a few shaped points (see Barham et al. 2002), or the harpoons at Katanda, if accepted (Yellen et al.

1995), but visible in general only within the last hundred thousand years (Villa and d'Errico 2001).

Structures present one of the longest doubt ranges. The hut or windbreak at Olduvai DK in Bed I (Leakey 1971) has often been doubted (e.g., Potts 1988). At Latamne in Syria, numbers of large stone blocks were collected and arranged (Clark 1968): they are accepted here, although others might require different kinds of evidence.

Hearths can be seen as structures, and are amongst the best evidence of controlled fire. Several early African sites have claims for hearths, but these are debated, including those at Chesowanja and Koobi Fora (Clark and Harris 1985). Gesher Benot Ya'aqov appears to have wide support at a date of c. 0.7 Ma (Goren-Inbar et al. 2004), rather older than early hearths in Europe at Beeches Pit and Schöningen (Gowlett et al. 2005; Thieme 2005). Fire is likely to have had a major role in improving food preparation and food quality (Wrangham et al. 1999). It might be seen as facilitating the expensive larger brain (cf Aiello and Wheeler 1995), but in the current state of investigations there is archaeological uncertainty about the earliest dates.

Special attention to bodies could be claimed from cutmarks on Stw 53 at Sterkfontein (Pickering et al. 2000). It is possibly inconsistent not to take more note of that, but the first example well associated with archaeology is Bodo in Ethiopia dated to about 0.6 Ma (White 1986; Rightmire 1996), where there is defleshing of the skull. This character recurs in a number of later individuals. The collection of human remains in Sima de los Huesos at Atapuerca is another case of similar date that probably qualifies as deposition showing special attention to bodies (Arsuaga 1998; Carbonell and Mosquera 2006; Pettitt in press).

Burial represents something more, both in practice and concept. The Middle East finds are the oldest, but it remains unclear whether the earlier examples are at Skhul and Qafzeh (Grün et al. 2005), or the Neanderthal burial at Tabun (Vandermeersch 2006). Either way, purely for the purposes of this exercise a date of approximately 100,000 is established.

In the case of ornament and decoration, dates have become older recently. Again, however, in most categories they do not exceed c. 100,000—as at Skhul, somewhat older than Blombos Cave (Grün et al. 2005; Henshilwood et al. 2002, 2004; Henshilwood and Marean 2003; Vanhaeren 2005; Vanhaeren et al. 2006).

The significance of other ideational or symbolic behaviour is less universally accepted, whether figurines as from Berekhat Ram, a rose quartz hand-axe from Atapuerca, or ochre in southern Africa (Goren-Inbar 1986; Goren-Inbar and Peltz 1995; Carbonell and Mosquera 2006; Barham 2004). Yet at the very least 'special attention to materials' is shown in a number of such cases. They could even be seen as special cases of the very long established selection of raw materials that goes back to the beginning of the archaeological record (Semaw et al. 1997, 2003).

Interpretation

This paper has contrasted the ideas of smooth curves and steps in the events of human evolution. The underlying issue is to know whether we are looking at one long trend, or rather sets of new impulses generating 'revolution.' Apparent smooth curves may be shaped through operation of a single model (e.g., social feedback); but equally, one evolutionary force may drive its effects through large numbers of single mutations at a biological level. In archaeology, we have primary evidence which must be described, but we are at risk of imposing step changes which may have little significance. Over-reliance on one line of evidence, or 'false concretisation' (stemming from the tendency to regard entities as real simply because they have been named), can have consequences if projected onto other disciplines—'unintended effects.' Archaeology can however attempt to gain independence from a priori 'beginning,' 'middle,' and 'end' models, and from criteria that depend excessively on a few aspects of just one segment of the record. One way to do this is through sequencing all the available individual traits.

The scoring of concepts/traits has limitations, but it seems at least as robust an approach as trying to measure things from a few tool types somewhat arbitrarily selected from lithic technology. Whatever the imperfections in the analysis, it is evident that there is a complex multidimensional record.

Steps in one area need not coincide with steps in another, but there may be relationships.

A few points can be summarised:

1) Cultural concepts or traits appear to accumulate steadily through the Pleistocene, more so than might be thought from a traditional Oldowan/Acheulean/Middle Palaeolithic/Late Palaeolithic outline.
2) There is already a considerable package of concepts/traits at the start of the visible record.
3) There remains a possible plateau at c. 1.5–0.8 Ma, coincident with the middle times of *Homo erectus* and the earlier Acheulean.
4) Thereafter traits accumulate again, not simply through the last 0.1 or even 0.3 Ma, but through >0.5 Ma.

One effect is to place increased emphasis on the period 0.7–0.5 Ma. Not only are various traits seen here, but they appear associated with *Homo heidelbergensis*, and the genetic evidence would suggest that its parent population diverged into ancestors of Neanderthals and modern humans through this same period (Green et al. 2006; Krings et al. 1997).

The large brain sizes, at least in some populations—e.g., Atapuerca and African specimens such as Saldanha and Bodo, when compared with modern cranial capacities, dispel the idea that a major size increase through the last half million years started at this point. The average of 1250 cc for several *heidelbergensis* specimens is c. 92% of modern volumes, little more than 1 sd from modern means. Thus any steep growth had already happened. Larger capacities seen in some last glacial Neanderthals and 'Cromagnons' have caught attention, but are above modern means, perhaps for some reason of selection operating locally.

In the classic social brain model, as given by Dunbar (e.g., 1998), it has been postulated that brain size has a strong relationship with social group size. This would be not the immediate group, but the network of contacts. The model does not in itself stipulate why a particular group size should be necessary, tending—on the basis of primatological evidence—to say that this depends on factors of ecology (Dunbar 1995). Social competition can be part of this scenario (Alexander 1979), and the feedback ideas from an earlier evolutionary biology may be invoked to account for the consistent prolonged trend (Huxley 1955). The figures used in this study suggest that if valid the basic social brain hypothesis is likely to operate right through the Pleistocene, but that brain size changes do not obviously provide some extra 'Factor X' through the last half-million years.

If this relative continuity is to be seen in the total accumulation of concepts or traits in material culture (as it appears), and in increases in brain size (with a certain amount of exception and cause for debate), what finally of the traditional steps in lithic industry classification, and numbers of tool types?

Here the changes merit more detailed study, partly because of the extent of variability, itself long admitted (Kleindienst 1961; Clark et al. 1966). Major technical changes are included in the concept scheme above. Although the concepts plot emphasises continuity, it is also hard to escape the impression that there are clusters of new (applied) ideas at 2.6 Ma, 1.6 Ma, 0.4 Ma, as well as within the last hundred thousand years. The question to return to is whether these are just artefacts of preservation and preconceptions.

The technical developments do seem to have an objective major importance, conferring practical advantages that depend on an adequate cognition. The bifaces give longer cutting edges, sharper edge angles, and far better leverage compared with Oldowan choppers. Hafting gives far more flexibility utilising the best properties of different raw materials. It both needs and stimulates greater shared knowledge of the world, with its emphasis on glues, binding, and maintenance. Analysis thus immediately leads out to other consequences, which are more social than technical.

It is easy to hypothesise that in a widely dispersed technically competent population, there was a large selective advantage on communication, and that the doubling in brain size is largely to do with language. If language then favoured a sort of sociocultural speciation by imposing barriers between groups, as suggested long ago by Isaac (1972), that would add to the force of selective pressures.

Finally, there is the issue, beyond all the criteria examined here, whether modern humans still require something 'extra' in explanation. It would seem fruitless to argue away the kinds of lists of additional characteristics and evidence in Stringer and Gamble (1993, 2007), d'Errico et al. (2003), or

Mellars (2005), including especially evidence of art, music, and rapid cultural change; although remnants of some other elements can be traced at earlier dates (such as tool standardisation). It does seem however that the changes derive from a general extension of social dimensions, rather than a simple addition of 'symbols' into the record. The preoccupation with demonstrating 'symbolic behaviour' as evidence for modern behaviour and language seems inadequate for gaining a broader perspective. Not only is there evidence in other primates of symbolic behaviour and capability in symbol use, but lines of anatomical evidence (Tobias 2005, Martinez et al. 2004), and the calculations of evolutionary anatomy and psychology (Aiello and Dunbar 1993), argue for language having much earlier roots.

Here it is noteworthy too that many of the newer features in cultural traits are intensifications of earlier ones:

Attention to body (before)—burial;
Attention to materials (before)—decoration, ornament;
Use of fire (before)—fire in ritual;
Use of wood and bone (before)—wood and bone in artefacts.

The intensification may be attributable at least partly to minds operating with additional levels of intentionality, a function of the demands of social worlds as discussed above. This perspective argues for one overall frame—a single gradient of 'becoming human.' Yet even the Neanderthal/modern divergence shows the possibility of stages, or different sets of outcomes based on earlier adaptations that were workable in their own right. There remain, across the lines of evidence, some indications of major sets of changes that may amount to grade changes.

Accepting these and that the recent intensification merits the label of a revolution, one can go on to argue that there were:

- A first revolution of attaining a basic human socio-cultural-economic package (c. 2.6–1.6 Ma).
- A second revolution, largely silent archaeologically, in which large brains and language evolved together in concert with factors such as fire use (c. 1.5–0.5 Ma)
- A third revolution, the final *sapient* intensification (with deep roots but gaining acceleration within the last 100,000 years).

In this reformulation there is a tension between the signs of continuity, and the ideas of revolutions (which Clive Gamble [2007] has also recently challenged in another formulation). Probably none of the revolutions would include all contemporary hominid populations. It may be said, of course, that in this paper we simply have *Homo habilis/erectus/sapiens*, or Lower/Middle/Upper, in another guise. But the whole point of the concepts analysis is to look at the record on a broader basis, and this schema arises from that examination. If in future we can demonstrate that cultural concepts/traits accumulated so continuously that there were no clear revolutions, all well and good. But in the meantime, the concept that there were *earlier* revolutions should help sharpen up criteria for testing the later ones.

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