

Full Title of the Article: Further Thoughts on Genetic Arguments for Handaxes

Short running title – Acheulean handaxes as a social phenomenon

Author name – John McNabb

Author affiliation and institutional address – Department of Archaeology, University of Southampton, Avenue Campus, Southampton, SO17 1BJ

Abstract – The Acheulean handaxe has always been considered as a social phenomenon. Corbey et al.³⁵ provide a major challenge to this arguing, quite rightly, that it has never been independently established that handaxe temporal depth is a product of intergenerational social learning. They take a number of assumptions integral to the social argument and suggest, using parsimony, that a genetic explanation is equally as plausible for each of them. Complex structures, in hierarchically nested routines of action, can be built in the natural world by organisms following pre-determined genetic sequences of actions triggered by external circumstances.

However there are some important points that the genetic argument dismisses that demonstrate an unequivocal social origin for the Acheulean handaxe. This article identifies those points and restores them to the debate. Parsimony affirms a social basis for handaxes, and does not require a theoretical genetic pre-disposition.

Keywords – Acheulean, handaxe, genetics, culture, *Homo erectus*, *Homo heidelbergensis*

Corresponding author/Author – John McNabb scarab@soton.ac.uk (023) 8059 3178

ORCID – 0000 0002 1841 4864

Author biography – John McNabb is Senior Lecturer in the Department of Archaeology at Southampton University, a former director of the Centre for the Archaeology of Human Origins (CAHO). His interests are in the technology of the Acheulean and what this can reveal about the social cognition of the hominins who made it.

Introduction.

The handaxe is one of the great iconic items of material culture found in the archaeological record of the Old World. The earliest examples are found in East Africa at c. 1.75 – 1.7 mya and South Africa between 1.7 and 1.6 mya¹⁻⁵ and coincide with the appearance of a new hominin species, *Homo ergaster* c. 1.9 mya⁶. Later forms of *H. ergaster* are labelled by some researchers as *H. erectus*, although there is some dispute as to whether these should be considered as two separate species or just earlier and later forms of the same lineage. Both are handaxe makers. Many researchers consider *Homo heidelbergensis* as a descendent of *H. erectus* in Africa. The youngest *Homo erectus* in Africa are from Daka and Buia dated to a little over 1.0 mya⁷, and possibly from Olorgesailie⁸. The earliest Heidelbergers are c. 0.7/0.6 mya and found in Africa at Bodo c. 0.6 mya⁹. Candidates for links between the latest Erectines and the earliest Heidelbergers are few in number^{10,11} but skull fragments from Gombore II (Melka Kunture, Ethiopia) may fit the bill⁸ at c. 0.85 mya. The African Heidelbergers are often given the species name *Homo rhodesiensis* in order to distinguish them from the Heidelbergers found in Europe and to whom the *Homo heidelbergensis* label is then applied^{8,12,13}. However, some authorities would like to see *Homo heidelbergensis* in Europe as the earliest of the Neanderthals¹⁴ and so, more technically they should be called the earliest *Homo neanderthalensis*.

Whether one or more species, polymorphic across two continents or otherwise, the Middle Pleistocene Heidelbergers (*sensu lato*) are also handaxe makers. This iconic tool form shows variability, in shape, in location and extent of cutting edge, in the many ways in which it was made, and in the kinds of blank upon which it was made. It is variously found in a wide variety of African and Eurasian environmental settings. Handaxes are usually bifacially thinned and shaped, but can on occasion be unifacial as well. In terms of their use they were on-the-ground hand held butchery and carcass processing knives¹⁵⁻²⁰, but had other functions as well^{21,22}. They should be considered as part of a processing technology as opposed to a hunting technology.

Handaxes are the most famous and recognisable element in a suite of material culture innovations that also appear at around the same time as *Homo ergaster*. Handaxes are often grouped with a whole series of large cutting tools (LCTs) such as cleavers, picks, and knives. The boundaries between these categories of tools can sometimes be difficult to identify²³. As used here, handaxes have a converging tip made by bifacial or unifacial thinning and shaping, and their cross section is usually lenticular or roughly so. This distinguishes them from cleavers which have a wide un-flaked tip, normally a product of the original prepared flake blank. Picks are thick and chunky, often triangular in cross-section with distinctly pointed tips and made from cobbles or thick blocks of raw material. Knives can have unifacial or bifacial thinning and shaping down one lateral edge, and a thick 'handle' or grip on the opposite edge, either natural (e.g. cortical) or a product of 'accommodation' retouch. In cross-section they are usually wedge shaped.

The handaxes and other LCTs form part of an innovative package of different tools and ways of making them that emerges with *Homo ergaster* and which is known as the Acheulean after St Acheul in northern France where these tools were first formally recognised^{24,25}. New ways of knapping large cores or boulders allowed for the production of large flakes, typically > 10 cm in length for use as LCT blanks^{26,27}. The early appearance of the full Acheulean package

is clearly evidenced in the Rietputs Formation of the Vaal River, South Africa. Recent refining of the dating suggests the earliest artefacts date to 1.6 – 1.7 mya and handaxes, cleavers and picks are present, made on either large pre-prepared flake blanks or on river cobbles⁴.

Both the preparation of the surfaces of the cores for preferential flake/blank removal, and the conceptualisation of the LCTs themselves as distinctive tool types, can be taken to indicate a cognitive evolution in *Homo ergaster* which distinguishes them from earlier hominins and their material culture. For the first time a pre-conceived form was imposed on the stone being flaked²⁸⁻³⁰, rather than allowing a form to emerge via the process of manufacture³⁰⁻³³. This is demonstrated by the repetitive character/process of blank manufacture, the LCT concept itself, as well as many of the LCT shapes which were then consistently reproduced.

This ability to conceive of a distinctive shape, and then realise it through knapping, implies that the hominins that made the Acheulean were able to ‘mentalise’ their world. This concept will be returned to later, but in cognitive psychology it refers to recognising that others will perceive the world through their minds in the same way that you do. Here I do not impute the same mentalising capabilities as modern humans, merely that holding and realising a pre-conceived concept (however derived) demonstrates the capacity to engage with the world through thoughts.

Both *Homo ergaster/erectus* and *Homo rhodesiensis/heidelbergensis* were producers of the Acheulean technological package. From its earliest manifestation in Konso, Kokiselei and Oldupai Gorge in East Africa, and the Vaal River in South Africa^{1,2,4,5} to the end of the period it was made c. 0.3/0.2 mya, the Acheulean has shown a remarkable homogeneity in its character, covering nearly 1.5 mya. It is found from Portugal in the west to the Loess Plateau of the Yellow river in China to the east, and from South Africa northwards to Wales. While temporal and regional variations clearly exist across time and space, the handaxe and the Acheulean package as a whole is effectively similar wherever and whenever it is found. This ‘variable sameness’ as Glynn Isaac called it³⁴ has been a puzzle for archaeologists since the early days of research.

The genetic challenge to handaxes as a social phenomenon.

One fact that has been almost universally agreed by investigators is that as a stone tool made and used by hominins in small social groups, the Acheulean and the handaxe were social phenomena. However, in the pages of this journal, Corbey and colleagues³⁵ suggested there was a genetic basis to the production of Acheulean handaxes. Their intention was to provoke debate by asserting that many of the pillars supporting the social explanation for handaxes could be easily explained by reference to pre-programmed-genetic sequences of action. They assert, and quite correctly, that since the first discovery and reporting of handaxes, and their integral role in the ‘Antiquity of Man’ debate in the middle Victorian era^{36,37} the cultural explanation has never been validated through independent testing. In this sense their avowed aim of challenging an assumption is most welcome. An important part of the social explanation is that the hierarchical routines of action involved in handaxe making are too complicated to be acquired by any mechanism other than social learning. However, Corbey et al. demonstrate, convincingly, that such complex behaviours, and the complex structures that emerge from them (e.g. bower birds’ nests, or patterns of tool use in certain bird species) can also arise from genetically pre-determined routines of action.

There have been responses to this challenge. Along with two colleagues, Robert Hosfield and James Cole, I provided a straightforward defence of the social interpretation demonstrating that various points more parsimoniously explained by the genetic interpretation, were in fact better understood through the lens of culture³⁸. In effect our argument was that just because the Acheulean has always been assumed to be a social phenomenon, does not mean that it isn't one, and that this conclusion is supported by patterning seen in handaxes at a number of different scales of analysis. My interpretations of the specific points raised by Corbey et al. are presented in (Table 1).

In the same volume Thomas Wynn and John Gowlett³² provided an intriguing alternative spin on both the cultural and genetic argument. Adopting a *gestalt* position they argued that the six basic physical characteristics that all handaxes share/require were an ergonomic response to the need for a large handheld cutting tool. All of the features supposedly explained by social learning could be explained from the simple practical necessities of conceiving and making a tool to do a particular set of jobs. The handaxe as a concept is social, but its physical reality becomes an emergent property of the integration of those six requirements. The distinctive shapes of handaxes are then explained as a best-fit accommodation to the integration of these factors; a globular butt, a point or elongated tip, a cutting edge, sufficient width to make a lateral edge and point functional, thickness and weight distribution which is important for different handaxes doing different jobs, and skewness where a hominin knapped a tool to suit the requirements of a dominant hand. Whereas social explanations privilege outline shape as being significant, and bilateral symmetry down the long axis with it, Wynn and Gowlett argue that handaxe shape is not selected for culturally (nor are we neurologically pre-conditioned to recognise handaxe shape as such). Instead, the pleasure-reward pathways in the brain respond to the sinuous curves and convexities in handaxe shape, and thus ensure that the 'shape-glue' that binds the ergonomic requirements together persists across generations. Bilateral symmetry in handaxe shape feeds directly into this as it is selected for via ancient anthropoid visual recognition systems in the brain. A critique of this dynamic new position on handaxes is not appropriate here, but my defence of the social explanation, below, will apply equally to the genetic explanation as well as to what I characterise here as Wynn and Gowlett's Goldilocks theory.

Culture and the Acheulean.

Before continuing it is necessary to explain my usage of the terms culture and social learning which will be used heuristically and interchangeably in this paper.

The study of culture and the influence of social environment on individual's actions (and the level of free will/agency they therefore truly possess when making material culture in a social context) has been a matter of intense scholarship in anthropology and archaeology for well over 150 years. It is fair to say there is no consensus as yet on how to explain the extent to which the external environment conditions individuals, and probably no one answer would fit all circumstances anyway. A literature review of the arguments cannot be attempted here, but Berger presents a good starting point to further engagement with this vast topic³⁹.

At the risk of caricaturing the immense complexities in this subject and in order for discussion to proceed, I will adopt a simple heuristic framework that I hope will allow the points I wish to make to be more easily contextualised. I am aware that such an approach may horrify many colleagues.

In one traditional outlook on cultural influence – an individual is born into a social world and that environment conditions all actions and responses to them. It is akin to moving underwater. Culture completely surrounds you, envelops you, determines your options and responses, and mediates your interactions with everything and everybody around you. This was a common archaeological conception of culture both pre- and post-Second World War stemming from the culture-historical approach of the 1930s^{37,40}. Its legacy and influence was felt in Palaeolithic archaeology into the 1960s and 1970s (this view of culture underpinned what I was taught as a post-graduate in the early 1980s). In my opinion this view also informed the interpretations of John Wymer and Derek Roe, the two most eminent British Palaeolithic scholars from the 1960s to the 1980s. It may well have underpinned France's most influential Palaeolithic researcher, François Bordes too – as exemplified in the culture vs function debate between Bordes and Binford in the 1960s and 1970s³⁷.

The theoretical initiatives which engaged later prehistory in the 1990s and afterwards³⁷ largely bypassed British Palaeolithic archaeology, but in the broader scholarship of Human Origins it did result in a move away from such normative views of culture and the greater use of analogies from primate research. The emphasis shifted from an over-arching culture to one aspect of it, social learning, and in particular how practice and knowledge were passed on from one generation to the next. Mithen's paper on the Acheulean vs Clactonian debate was a very early foray into this⁴¹. There appeared a greater synergy between chimpanzee tool cultures and how hominins learnt to make Oldowan tools^{42,43}, than there did between the handaxes of *Homo erectus* and the agency of the axe makers of the Neolithic. Arising from primate studies was a greater engagement with cognitive evolution and how this would affect social environments and social learning within them⁴⁴.

In recent years there has been a shift within social learning research on the Acheulean to see the delivery of intergenerational knowledge as the result of influential role models^{45,46} whose practices may differ, yet together still form the small social groups within which most researchers believe the handaxe making hominins lived. Such a concept has intriguing ramifications. Unlike earlier conceptions, not everything made by a hominin group need look the same. On the one hand this would explain the diversity in handaxe shapes present at small primary, or near-primary context Acheulean sites such as Caddington, Round Green, Hoxne and Foxhall Road in the UK^{47,48}. Here hominin young learnt from different mentors how to make handaxes, the result being diversity in handaxe shape. On the other hand, it does not explain the persistent signal at sites like Boxgrove⁴⁹ where handaxe uniformity is present across possibly three generations over potentially a hundred years or less⁵⁰. However, we should be wary of applying one explanation to every situation.

If inter-generational social learning through role models does not always lead to uniformity in material culture, where else in a hominin's life might it be found? Repetitive patterns of learned behaviour could be limited to knowledge about the day to day business of how to survive; knowing how to hunt, how to stay safe, how to move through the landscape and how to acquire food. Hunting and food gathering may have required repetitive behaviours whose very uniformity ensured success and whose repetitive character were a result of their being tried and tested over time (i.e. you stalk this kind of deer this way, but that kind of deer a different way; don't eat those mushrooms). In this sense, persistent cultural transmission with high fidelity (traditions) would be confined to natural history and how to survive it⁵¹.

As I have argued elsewhere ¹⁶, there may be two basic patterns in handaxe form - those with a cutting edge all the way around (or nearly so), and handaxes with cutting edges confined to the tip or upper two thirds of the axe. Some groups may have favoured one or the other, and some included both forms. This should not be seen as a reconfiguration of the pointed vs ovate dichotomy of Derek Roe (1968), as shape is not a factor here. This basic division was what was handed on from generation to generation – the primary substance of intergenerational social transmission. Within each broad subdivision there was plenty of room for variability and more localised bodies of knowledgeable practice to be handed down, depending on which role model you were imitating and which Acheulean group you lived in. So with an emphasis on cutting edges, handaxes were both a mental construct ⁵², an idea of the kind of tool needed to get the job done, as well as a cultural phenomenon. Within that overarching influence, individuals were free to follow one or more role models, and learn and adapt to their own particular satisfaction. This is where the variability within and between handaxe assemblages originates.

As a heuristic framework I will adopt this as my default view of handaxe making social learning in the Lower and Middle Pleistocene. Again, I am aware this is controversial. The above may appear an unnecessary and speculative detour in a paper critiquing a genetic explanation of handaxes. However, since my arguments will be a defence of a social explanation for the Acheulean I believe a clear understanding of what my vision of that sociality is may help readers to contextualise my arguments.

Some planks of interpretation.

There are a number of interpretative ‘planks’ that are important to acknowledge in a discussion such as this. They cross-cut the social argument and underpin any social interpretation of handaxes. Admittedly, some are assumptions while others are supported by varying degrees of evidence. Corbey et al.’s argument is weakened by not engaging with them.

1. Erectines and Heidelbergers are group living and socially co-operative animals. The direct evidence for this is scarce. It is an inference, but not an unreasonable one. In the various landscapes that Lower and Middle Pleistocene hominins occupied over time, in Europe and Africa, a number of rival predators would have competed with them for food and living space. Most of these were bigger, faster, stronger, meaner, and had bigger teeth and claws. For a biped with few natural defences, group living was a necessary pre-requisite for survival ^{41,53,54}. There are any number of examples of socially complex, hierarchically organised, predators (African wild dogs, hyena, wolves etc.). Hominins were just another.

The evidence of hearth-like concentrations of fire use at Gesher Benot Ya’acov at >780 kya ⁵⁵, and Qesem Cave ⁵⁶ at c. 300 kya, both sites in Israel, and at Beeches Pit, UK, at >400 kya ⁵⁷ around which tools were made or repaired, is suggestive of group activity. Fire evidence at Swartkrans at 1.0 mya, and ashy horizons within the cave at Wonderwerk, both in South Africa ⁵⁸ are equally suggestive. More cautiously, Foxhall Road, probably MIS 11, UK, is another example of a group of hominins round a fire ⁵⁹. In this case the hominins brought their handaxes already made with

them to the locality and, at this site, demonstrated the diversity of mentor copying suggested above.

Hunting evidence too is suggestive of group activity, though whether as a single social group, or following primate models of hunting coalitions is unknown. The potential for seven handaxes manufactured around the horse carcass at GTP 17 Boxgrove c. 0.5 mya, UK, ^{50,60}, or the horses mired at Schöningen ⁶¹ MIS 9, Germany (by a non-handaxe using group) imply socially co-operative groups; the knapping floor at the Lower Loam Swanscombe (MIS 11; UK) is also a possibility ⁶², where upwards of nine different flint nodules were brought to help process a fallow deer carcass. Butchery practices at Qesem Cave in Israel also suggest group activities ⁶³. Hunting large and dangerous fauna requires social co-operation – rhino at Boxgrove ⁵⁰, elephant at Southfleet Road ⁶⁴, UK, (with the excavator suggesting a group of between four and thirteen hominins involved in the butchery), and Mwanganda's Village ⁶⁵, or buffalo at Melka Kunture ⁶⁶, if not scavenged carcasses, imply socially co-operative activity.

At Ileret, Kenya 1.5 mya, footprint trails have led to the suggestion of a group of male Erectines moving across a lake margin as a group, though whether as a social unit or a hunting party is not known ⁶⁷.

2. From almost their very first conscious experiences, young Erectines and Heidelbergers would have grown up seeing and hearing handaxes being made and used, broken and discarded, lost, repaired and reused, every day of their lives, or at least on a very regular basis. So by the time they came to make their own first handaxe they would have been intimately aware of them, what they were used for, and of the processes by which they were made. This is a key point that should have been built into Corbey et al.'s argument from the outset, and also has implications for Wynn and Gowlett ³² as well. Young hominins would be intimately aware of their importance in contributing to getting food (and other tasks). All this within a social context. This is a point which simply cannot be ignored, or conveniently side lined. A geneticist's reply might be that this is where the social input comes from in a dual inheritance type of argument (Table 1). However that doesn't work for me. The young hominins have grown up with handaxes. At no point can a hominin's own understanding of a handaxe be parsed from its social context (and point 1 above feeds directly into this). This isn't the fine social tuning overlying a genetic basis, this is the basic social substrate of how where and when handaxes were made.
3. The young hominins will learn handaxe making by imitation learning through the observation of role models (as above, and drawing from primate analogies). How hominins acquired knowledge about their world is a contentious topic with both primate (non-linguistic/observational) and more human centred (direct or indirect instruction/linguistic) models being applied. Although hominin capacity for speech is unclear, some evidence suggests they did not have the physical capacity for the production of the same range of sounds as modern humans, at least for *Homo erectus* ⁶⁸, and by implication its Heidelberg descendent. However, a proto-language of

sound-concept/object associations, lacking complex grammatical structure is by no means impossible.

Learning in a non-linguistic or proto-linguistic context would place a high value on visual stimuli ⁶⁹. Studies have shown that it is very difficult for novices to reproduce the process of handaxe making, and thus make successful tools, simply by observing just the handaxes themselves, known as emulation or end-state copying ^{70,71}.

Experimental studies demonstrate that imitation learning is more effective.

Technically this is process copying, in this case understanding both the way the artefacts are made as well as their end states ⁷¹. At Boxgrove experimental studies strongly suggest that the application of effective platform preparation must be learnt by individuals, it is not intuitive ⁷². Given point 2 above, imitation learning is a reasonable starting point for understanding how Erectines and Heidelbergers learnt how to make and use handaxes. Some instruction in a proto-linguistic context may have been possible. The point here is that if hominins grew up in social groups and saw handaxes being made and used from an early age, then the existence of social learning is a much more parsimonious interpretation than positing as yet undiscovered genetic routines. Experimental evidence suggests that imitation learning, in a non-linguistic context ^{71,73}, is a perfectly adequate mechanism for imparting sufficiently complex ideas such as handaxe making. However, it may not be able to convey higher levels of complexity or ratchet up the quantity of cultural knowledge imparted – a possible contribution to understanding the long stasis in the Acheulean ⁷³.

4. More controversially, hominins possess theory of mind and this will influence social stimuli and social learning. ToM as it is abbreviated to, is a concept widely used in behavioural and cognitive research ^{71,74}, though different disciplines often use it in different ways. It involves the recognition that another individual has a mind, as do you, and that like you they can access their thoughts and act upon them. This is where the notion of handaxes as imposed form, as well as prepared core/boulder surfaces for handaxe blanks, both come in as evidence for mentalising. The archaeology bespeaks the capacity to hold discreet ideas in the mind and to act on them. It also implies that the intended goals and actions of others were understood by Acheulean hominins. The intention to make a handaxe by first making a flake blank will be understood by other watching hominins as they too will follow the same process when they wish to make and use one. Watching someone knapping, as you have done all your life, implies an understanding of another's goals and intentions. Acquiring handaxe knapping skills via imitation learning implies ToM because it recognises the intended goals and actions of mentors and peers. The evolution and original significance of the mirror neuron system ^{98,99} remains a matter of debate. However its linking of the observation of tool assisted action to the empathy circuitry in the brain, may have added to the effectiveness of imitation as a social learning strategy. Modern neurological studies suggest that understanding the goals and intentions of others is a powerful aid in both learning and teaching⁷⁵.

ToM also involves the recognition that others may hold a different view of how the world works than you do. These are labelled false belief states, and are for many

primate researchers the corner-stone (and only litmus) of ToM. While many evolutionary researchers have engaged with the cognitive implications of ToM^{54,76}, incorporating false belief states into material culture research has been more challenging from a methodological perspective. Thirty years on from a landmark paper on ToM, Call and Tomasello⁷⁷ summarised the state of research on primate ToM in 2008. They averred that chimpanzees did have an understanding of the goals and intentions of others and also understood the perceptions and knowledge of others. They had a ‘perception-goal psychology’. However, they were not able to understand false belief-states, so unlike humans they did not possess a ‘belief-desire’ psychology. More recently experimental work on enculturated apes has adapted the classic Sally-Anne test for recognising ToM through false belief states (if I interpret the papers correctly), to a non-linguistic version designed for testing apes⁷⁸. Using gaze direction, the experimenters assert they have successfully demonstrated an awareness of false-belief state in great apes. Call and Tomasello were authors on this paper. Although these results are controversial, if validated they would imply that ToM is not predicated on language.

The importance of ToM is that it confers specific advantages to a hominin which could prove selectively advantageous. ToM is a way of divining the goals and intentions of others by ‘mentalising’ rather than just behaviour reading^{98,99}. When allied with an understanding that others have a different perspective than yourself, and so may act differently, this provides a powerful evaluative component to assessing the consequences of actions. *How can I manipulate social circumstances to enhance my own position? How will my performance be seen in this situation? Should I join the obvious hunting coalition, or is there some longer term tactical advantage to allying with a less prominent one?* While I am not suggesting that ToM and evaluative potential in *Homo erectus* and *Homo heidelbergensis* are the same as in *Homo sapiens*, nevertheless a certain level of conscious evaluation could affect selection on individuals by enhancing positive selective opportunities.

How do these interpretative planks impact on a genetic argument for handaxes? Firstly, they empower the social explanation of handaxes by demonstrating how deeply embedded in a social context this kind of material culture really was. Handaxes and other LCTs cannot be extracted from that social context and interpreted in isolation as Corbey et al. have done. I accept that some of the above is speculative, but no more so than an as yet unidentified suite of genes or expressed sequences of behavioural patterns. Moreover, I contend the above is perfectly reasonable given what we know about handaxes and Acheulean lifeways. The above makes a social context more parsimonious as an explanation for handaxes than genetics. Secondly, if Corbey and colleagues wish to promote a genetic explanation then they must thoroughly disprove the above, or something like it, rather than simply side lining it as will be discussed below.

Functionality and an important plank in Corbey et al.’s argument

As will be seen (Table 1) a key component of the genetic argument is that social learning will inevitably produce copying errors and that these will ratchet up and accumulate over time. Handaxes as a product of social learning should show endless variability. Why then do they

not? The reason, according to the geneticists, must be that some other mechanism is constraining shape and basic morphology. It cannot by definition be a social constraint because social mechanisms inevitably lead to the proliferation of variability. Something else must be going on.

In our response to the geneticists³⁸ we critiqued the experimental basis on which the copying error argument was given a value of 3-5% error per iteration. The work of Kempe and colleagues⁷⁹ using 'iPads' and asking experimental subjects to resize images of handaxes is simply not a realistic test of knapping fidelity. It has important insights for modern humans, visual memory and perception, but is not really relevant to handaxe making by Middle Pleistocene hominins. In (Text Box 1) the question of what exactly a copying error might be, in terms of a handaxe is considered.

From (Text Box 1) some obvious questions arise. On the one hand you could dispute whether an idealised target form for a handaxe actually existed in hominin groups. In my personal view of hominin society presented earlier, such a template would not always be present. Then again, how would we separate the inter-generational copying errors from those just made on a bad day, or the novice who soon perfects his or her craft and starts to approximate the desired form? If only 5% of an assemblage is a copying error, then 95% of it must be at least adequate, attesting to considerable fidelity in transmission. Why should the 5% gain overall significance? Finally, there are distinct methodological difficulties associated with identifying modal forms in palimpsest assemblages (which most handaxe assemblages actually are). If it is hard enough to identify the modal pattern, how can you identify the variations that depart from it? If nothing else, such concerns would render the genetic argument difficult to operationalise for empirical testing.

In addition to the above there are three arguments that contribute to morphological stability in handaxes, one of which (the first) was acknowledged by Corbey and colleagues. These are functional considerations, range of possible shapes, and mechanical constraints in manufacture.

Figure 1 near here. One quarter page size across two columns

Corbey et al. cite a number of references on the function of handaxes but set up this aspect as if it is a highly contested area. It is not, as we were at pains to point out in our reply³⁸, and no one has taken the hypothesis of handaxes as throwing weapons seriously for many years⁸⁰. Corbey and colleagues downplay the wide spread agreement amongst researchers that handaxes are carcass processing/butchery tools, amongst other possible uses, which is supported by a number of micro-wear studies³⁸. Stability of shape arising from pragmatic considerations is exemplified in a simple analogy. Modern steel knives can show a bewildering amount of variety in the fine details of shape, decoration, size etc., much of it cultural, yet the basic design is unvarying, governed by the uses to which it is put. They all share a handle and a blade and often a guard separating the two. Blades can be single or double edged and pointed or not depending on the use it is to be put to. It is the same for daggers and bayonets, swords and butter knives. The basic *bauplan* does not change because it doesn't need to. This need not be a cultural thing, a point Wynn and Gowlett³² acknowledge. In terms of handaxes the analogy is relevant. Whether they have an all-round cutting edge, or the cutting edge is confined to just the tip/upper part, handaxes are made to be used – they are a device for getting a cutting edge to a job. The requirements of a suitable

cutting edge and maybe a point imposes certain constraints on the overall shape of the tool. They stay roughly the same for a very long time because they don't need to change; they work in any kind of environment.

The second point concerns outline and planform. In suggesting that copying errors will generate so much variability, it is legitimate to ask just how much possibility for shape change actually is there in a handaxe? A simple example utilising some old data ⁸¹ will demonstrate this. In (Figure 1) a series of basic handaxe outlines are presented. While it is acknowledged these few shapes are underestimations of true potential they do not underestimate the variability by too much – at least for the very basic outlines. It is quite difficult to imagine other shapes. While each of the six UK Middle Pleistocene sites can be characterised by a focus on a particular range of outlines, all the sites include other shapes as well. This was a point made in Roe's original handaxe work ⁸². We might perhaps ask why we never see right angles and squares in Middle Pleistocene handaxes? Given the point just made about cutting edges, there are not that many shapes that could be morphed and still serve the requirements of delivering a serviceable edge. This feeds directly into (Text Box 1).

Figure 2 near here. One quarter page size across two columns.

The third constraint concerns handaxe blanks and the process of manufacture. It is often cited that hominins could make what they wanted out of any blank. In some cases that is true, but not always. A flat flake blank could be knapped into any shape, whereas a cylindrical nodule would be challenging for an ovate maker ⁵². If we look at the simple outlines in (Figure 1) they could all be manufactured from a stylised wide flat blank as in (Figure 2). Elsewhere ⁸³ I have suggested that shape change (variability in Corbey et al.'s terms) is a repositioning of surface area either side of a perceived midline. At first glance this would seem patently obvious. But if we think of the blank (Figure 2) as a surface of potential variability, perhaps akin to Tennie et al.'s zone of latent possibilities ⁸⁴, shape is imposed by removing or leaving surface area, and thickness. Variability in outline shape reflects differences and shifts in the location of surface area. This in itself imposes some limits on what can be made. If this is then mapped onto the cultural predisposition to make handaxes with cutting edges all the way around the circumference, or just on the tip/upper two thirds of the tool (as suggested above), then there is a clear constraint on just how much variability a knapper could produce before he or she even began to copy or adapt the patterns of a role model. For example, if the inter-generational knowledge transfer in your group involves simply passing on the notion that a handaxe has a cutting edge all the way around (many groups may share this concept), and your particular group uses a soft hammer (a local tradition not necessarily shared by every other group) you are most likely to end up with an invasively thinned ovate or cordate shape, even before you begin to copy the variations on this theme that are present within your group's repertoire.

A limited shape-drift model also engages the possibility that at some point later iterations could re-invent the shapes of earlier ones further inhibiting the proliferation of variation that social learning is supposed to generate.

So, there are natural and powerful constraints on handaxes morphology, constraints that need not be cultural, though they could be in some cases, and which will automatically limit shape variability without any need for invoking endless proliferation of shapes or a genetic explanation. The conservatism seen in handaxes is *in part* explained by these.

Difficulties and data.

In light of the clear importance of copying error and the increase in variation to the genetic argument, it would be useful if this could be explored by reference to empirical handaxe data. Immediately we run into difficulty here; some methodological concerns have already been alluded to. Given that most assemblages of handaxes are palimpsests, accumulated over an unknown duration, how are we to recognise the copying errors from the target templates of the previous generation? As we noted in our reply ³⁸ Boxgrove is one of the few sites where the scale of data resolution is sufficient to pick up intergenerational change, perhaps in this case over as much as three to four generations. Yet even at Boxgrove we have no way of parsing the handaxes of an earlier generation from the later ones. This really can only be done on stratified sites. Yet even here a methodological problem presents itself. Leaving aside the palimpsest issue, if populations or groups changed over time, then the handaxe morphology clock is reset to zero and any change between higher and lower layers is not going to be a result of copying errors, further complicating the ability to demonstrate a genetic explanation.

Data sets that will facilitate testing are rare. One of the few of sufficient size where a consistent methodology has been applied (and by one analyst in this case) is the Marshall et al. database curated by the Archaeology Data Service ²³. It is based on the measurements and indices developed by Derek Roe ^{82,85} (Figure 3). Yet even within this resource the number of stratified sites or localities with appropriate chrono-stratigraphically distinct assemblages is limited. Of the 18 sites in the database only 3 (Tabun, Montagu Cave, Casablanca/Sidi Abderrahman) have stratigraphically distinct layers or diachronic locations with sufficiently large enough samples.

On the other hand, the Middle Pleistocene chrono-stratigraphic sequence of the UK is now very well understood and allows for a clear appreciation of diachronic variability in handaxes. UK sites from the Marshall database can therefore be included. Comparable data from the Cave of Hearths, South Africa ⁸⁶ was kindly provided by Hao Li ⁸⁷. This site was chosen because it has three stratified handaxe layers.

Figure 3 near here. One quarter page size across two columns.

I will only describe the Casablanca sequence ⁸⁸ and the Cave of Hearths ⁸⁶ in detail, and give the results of the other sites in brief.

(Figure 4) presents a PCA of the five Roe indices (Figure 3) for Casablanca (Sidi Abderrahman) generated in the statistical software package PAST. The loadings' plot (not presented) indicates that PCA 1 (horizontal) is dominated by the measurements of the tips and bases (T1/T2 and B1/B2) with a less significant contribution from shape (L1/L and W/L). On the right side of the horizontal axes (+) tips are thicker than the basal thickness of the handaxes, and narrower in relation to the basal width. To the left of the horizontal axis (-) the tips become narrower and thinner than their bases. On the vertical axes the loadings' plots demonstrate that tip and base thickness (T1/T2) and the overall refinement of the handaxe (Th/W) account for the majority of the variation on the axis, correlating negatively with basic shape (W/L) – as the first two increase the latter decreases. At the top of the axis (+) the handaxes and their tips tend to be relatively thick and the handaxes themselves elongated, becoming shorter and thinner toward the bottom of the axis (-).

(Figure 4) shows the three different chrono-stratigraphic localities from the Casablanca area. It is evident that, in general, the STIC quarry, the oldest locality, has less variability than the younger locations. A MANOVA test confirms the statistically significant difference between the three locations. What the PCA shows quite nicely is the drift in shape across the potential morphological space from the left and higher part of the diagram towards the lower part - handaxes generally become thinner and wider and less pointed. I suggest this is not a proliferation of new shapes (or an accumulation of copying errors) but a gradual shift toward increasing emphasis on some characteristics that were already present in the assemblages. A shift in the locus of diversity.

Figure 4 near here. One half page across two columns

By contrast, the Cave of Hearths in South Africa shows a different pattern (Figure 5). Here samples are small but the three beds were carefully excavated^{86,87,89,90}, and the sample supplied by Li et al. is a good representation of the handaxes from the three beds (pers. obs.). The three beds sit directly on top of each other. How long the beds took to accumulate, or the time interval between them is unknown. They represent three phases of an accumulating talus cone forming just within the cave's entrance with Bed 3 being the highest. For PCA 1 both B1/B2 and T1/T2 enlarge together. On the right hand of PCA 1 tips are wide and almost as thick as the bases are, and although the axes can be quite wide (more than 0.75 of L) the point of maximum width is quite low down. On the left of the axis the tips are narrow and thin and the handaxes have even lower centres of gravity (low L1). Size and shape (L1/L and W/L) play a variable part, and teasing out their significance on a handaxe by handaxe basis for this site is more difficult. A MANOVA on the three assemblages shows no statistically significant difference between the five indices at the site. The paucity of handaxes in the halo outside of the 'core' forms common to all three assemblages, particularly in Bed 1 implies this. For the Cave of Hearths then there is no significant drift in handaxe shape over time and no marked tendency to increasing or decreasing diversity.

Figure 5 near here. One half page across two columns

The data for Montagu Cave⁹¹ in South Africa (data not presented) continues the theme of variability. There are two main handaxe layers, Layer 5 (oldest/lowest, undated) and Layer 3 (youngest/highest, undated). They are separated by sterile layer 4 of unknown duration. Most authorities consider the two assemblages to be squarely Middle Pleistocene. A MANOVA showed a statistically significant difference between the two assemblages (Wilks' lambda 0.8705, df1=5, df2=111, F=3.302, p=0.00809). For the most part the two layers share the majority of the variation in handaxe form (overlap between L5 and L3 on the PCA), with L3 having a small number of handaxes which are thicker at the tip than the base, while the lower and earlier L5 has somewhat more narrower and thinner tipped handaxes. But the differences between the two assemblages are not that pronounced.

The Achello-Yabrudian site of Tabun in Israel (data not presented) has a number of layers containing handaxes, layer Ed is stratigraphically lower than Layer Eb, though some dating techniques (TL on burnt flint) reverse the ages of the layers⁹². For our purposes the two layers are between 350 and 300 kya and the stratigraphic super-positioning is all that need concern us here. There is a statistically significant difference between the two assemblages (MANOVA, Wilks' lambda 0.9013, df1=5, df2=125, F=2.737, p=0.02208), but the strength of the difference is not particularly marked. Again there is a considerable zone of overlap in

the shape variability between the two levels with the older and lower layer having a little more variability seen in lower L1s with changes in the width and thickness of the tips relative to the bases.

What all these PCAs actually show is that most assemblages share a common set of handaxe outlines and refinements and then express any distinctiveness through forms that lie outside of, or to one side of, the common pool of shapes. What appear at first glance to be losses and gains in diversity over time, are in fact shifts, or drift from one part of the range of possible forms (zone of latent possibilities) to another. Points that were thick or thin, wide or narrow change, and bases and middles can do the same. This feeds directly into the observations made above. Mechanical (and functional) constraints will limit the range of potential morphologies; there are only so many shapes that can be made when you want a hand-held butchery knife made by bifacial thinning and shaping. What these data are suggesting is that over time, the makers of handaxe assemblages explore the range of possibilities *that are open to them*, for whatever reason, be it cultural or something else. Shape is not being irretrievably lost or changed, it migrates backwards and forwards over time.

To complete this section and emphasise one point, I will briefly present a PCA of the British data from the Marshall et al. database²³. The British chronostratigraphic Middle Pleistocene record is now tightly constrained within a framework which is relatable to the Marine Isotope record and in some cases even to stadials and inter-stadials within it^{93,94}. In (Figure 6) the Roe data (as in Figure 3) for eight UK Middle Pleistocene sites from the Marshall et al. database are presented. Full site descriptions and references can be found in a number of texts along with more detailed references^{47,48}. The tabulated data in the figure presents more detail on the sites included.

Between the controversial allocation of the rolled/abraded series of handaxes from Warren Hill to MIS 15, and the less controversial MIS 13 allocation for Boxgrove, and the lightly rolled handaxes from Warren Hill, we can see what would seem like a slight loss of diversity (MIS 13 ellipse inside of MIS 15), although here that is argued to be a shift across potential morphological space. Notice that the MIS 13 data set does not fall outside of the limits set by the older one, it just moves towards one edge. So MIS 15 Warren Hill (abraded sample) and MIS 13 (Boxgrove and Warren Hill lightly abraded sample) share many outline shapes, but the latter have a somewhat more pronounced emphasis on one part of that common range.

Next, there is a difference between these sites which pre-date the MIS 12 Anglian glaciation, and those that come after it, as indicated by the change in the direction of the MIS 11 ellipse's axis. Nevertheless, there is still a considerable portion of shared potential morphological space between the three data sets. White, Bridgland and Foulds would explain this as a cultural replacement - new handaxe makers crossing the La Manche channel at the beginning of MIS 11^{95,96}, and the patterning in the data presented here would not necessarily contradict the differences described by these authors.

However, the drift is significantly increased in the MIS 9 site of Broom and the MIS 9 or 7 site of Cuxton. It is with this last site that a real change in the shape of handaxes occurs as is seen in the figure. This has been noted elsewhere¹⁶. Again, White and Bridgland⁹⁵ would see this as an expression of new handaxe makers arriving with new ideas about LCTs and what handaxes should look like (greater emphasis on cleavers, and ficron shaped handaxes). Here, an apparent increase in diversity is actually explained by demographic changes. Cuxton, for

example, has an eclectic mix of extreme pointed forms as well as other outline shapes, while Broom's LCTs have high incidences of clear asymmetry in their outline⁹⁷. The tighter emphasis on handaxes with a cutting edge all the way around, or nearly so, seen in the pre-MIS9/7 interglacials¹⁶, is less pronounced in the later Middle Pleistocene.

Figure 6 near here. One half page over two columns.

From the PCA's presented above, the lack of a single trajectory of ever-increasing diversity for a data set, or even a single clear trajectory at all, warns against the patterns that Corbey et al. imply would result from unchecked copying error. Copying error may well apply to handaxes to some extent but not to the extent predicted by experimental data. There are social and physical/conceptual checks inherent in handaxe making. The model of population replacement, essentially a cultural model, forwarded by Mark White and David Bridgland^{94, 95} and supported by McNabb et al.¹⁶ is sufficient to explain the relocation of emphasis on shapes. The pre-MIS 9 groups tended to make handaxes with cutting edges all the way round, and explored different potential variations within this on a group by group basis. The MIS 9 and later hominins explored a wider range of handaxe shapes and included more extreme variations such as long elongated shapes in addition to other LCTs. Within these imposed social constraints, role models and individual preferences could account for the variation remaining.

Conclusions.

The challenge to a social basis for handaxe making is a timely and important one, and ultimately makes a relevant contribution to debates as it asks us to be clearer about the assumptions upon which we base much of our understanding of the Acheulean.

The argument of Corbey et al. is rooted for the most part in parsimony. They argue that many of the foundations upon which the social explanation of the Acheulean is built can in fact be more simply explained by genetics, and analogies are offered which demonstrate how complicated structures can emerge out of genetic sub-routines which result in hierarchical and complex behaviours and material end products.

The argument I present here, and which we touched upon in our earlier response³⁸ asserts that Corbey et al.'s position is too simplistic, and ignores the nuanced complexities that surround handaxes. Or put more simply, and with respect, they haven't really understand handaxes properly. The history of handaxe research ought to warn us that a single answer that must apply to two distinct hominin species over more than a million years of time should be treated cautiously.

Young hominins grow up watching handaxes being made and used. This is a social context that simply cannot be ignored or side lined. It is not the social icing on the genetic cake, it is the fundamental ingredient in the mixture. While primate studies demonstrate copying errors occur in inter-generational knowledge transfer, genuine constraints exist on the potential for shape proliferation (error in Corbey et al.'s terms) in handaxes. The archaeological record, such as it is, shows outline shape drifting across a zone of potential shapes that these constraints impose. Sometimes assemblages seem to acquire new variation (drift in one direction), while at other times they seem to lose it (drift in the opposite direction). Alternatively the common pool of shapes doesn't really change over time (stasis). In fact diachronic variability in any direction, when it can be demonstrated, is a shift in the 'halo' of

shapes that surround common shared outlines which themselves move, but more slowly. Speculating, the role of social learning in terms of handaxe shape and extent of cutting edge, may be seen in the tension between centre and periphery – the influence of more traditional role models (or groups entirely composed of them – the shared outlines; Boxgrove, Cave of Hearths), and those groups with a wider variety of knappers to copy (the periphery or halo where more diverse role models explore the wider potential of the available options).

Of course, none of the above is *direct* and *absolute* proof of handaxes being socially conditioned, but it is clear evidence that the precepts upon which a genetic challenge is based can be successfully countered by a cultural argument. Social learning can embrace the nuances and ambiguity in the archaeological record far more effectively than a dual inheritance framework.

So which is more parsimonious, unidentified and hypothetical genetic routines, or the reality of stone tools made by individuals in social groups who grew up watching them made?

Acknowledgements - I would like to express my gratitude to Rob Hosfield and James Cole, collaborators on an earlier paper on this topic, for allowing me to explore these ideas in more depth. I am also grateful to Rob Hosfield for comments on a draft of the manuscript. Thanks go to Dr Li for generously sharing his Cave of Hearths data ahead of publication.

Conflict of interest statement. The research was unfunded. The author declares he has no conflict of interest.

Data availability statement. All data used was from already published sources, with data available through those sources; see references 23 and online supplementary data for reference 87.

References.

- [1] Bayene Y, Katoh S, WoldeGabriel G, Hart WK, Uto K, Sudo M, Kondo M, Hyodo M, Renne PR, Suwa G and others. 2013. The Characteristics and Chronology of the Earliest Acheulean at Konso, Eithiopia. PNAS 110:1584-1591.
- [2] Lepre CJ. 2011. An Earlier Origin for the Acheulean. Nature 477:82-85.
- [3] Gibbon RJ, Granger DE, Kuman K, Partridge TC. 2009. Early Acheulean Technology in the Vaal River Gravels, South Africa, Dated with Cosmogenic Nuclides. Journal of Human Evolution 56:152-160.
- [4] Kuman K, Gibbon RJ. 2018. The Rietputs 15 site and Early Acheulean in South Africa. Quaternary International 480:4-15.
- [5] Díez-Martín F, Sánchez Yustos P, UribeArrea D, Baquedano E, Mark DF, Mabulla A, Fraile C, Duque J, Díaz I, Pérez-González A and others. 2015. The Origin of The Acheulean: The 1.7 Million-Year-Old Site of FLK West, Olduvai Gorge (Tanzania). Scientific Reports 5:17839.
- [6] Lepre CJ, Kent DV. 2015. Chronostratigraphy of KNM-ER 3733 and Other Area 104 Hominins From Koobi Fora. Journal of Human Evolution 86:99-111.
- [7] Shultz S, Nelson E, Dunbar RIM. 2012. Hominin Cognitive Evolution: Identifying Patterns and Processes in the Fossil and Archaeological Record. Phillosphical Transactions of the Royal Society Series B 367:2130-2140.
- [8] Profico A, Di Vincenzo F, Gagliardi L, Piperno M, Manzi G. 2016. Filling the Gap. Human Cranial Remains from Gombore II (Melka Kunture, Ethiopia; ca. 850 ka) and the Origin of *Homo heidelbergensis*. Journal of Anthropological Science 94:41-63.
- [9] Wood B, editor. 2011. Wiley-Blackwell Encyclopedia of Human Evolution. Hoboken, NJ: Blackwell Publishing.
- [10] Gallotti R, Mussi M. 2017. Two Acheuleans, Two Humankinds: From 1.5 to 0.85 Ma at Melka Kunture (Upper Awash, Ethiopian Highlands). Journal of Anthropological Sciences 95:1-46.
- [11] Baab KL. 2016. The Role of Neurocranial Shape in Defining the Boundaries of an Expanded *Homo erectus* Hypodigm. Journal of Human Evolution 92(1-21).
- [12] Manzi G. 2016. Humans of the Middle Pleistocene: The Controversial Calvarium From Ceprano (Italy) and its Significance for the Origin and Variability of *Homo heidelbergensis*. Quaternary International 411:254-261.
- [13] Meyer M, Arsuaga J-L, Filippo C, Nagel S., Aximu-Petri A, Nickel B, Martinez I, Gracia A, de Castro JMB, Carbonell E, Viola B and others. 2016. Nuclear DNA Sequences from the Middle Pleistocene Sima de los Huesos Hominins. Nature 531:504-507.
- [14] Stringer CB. 2011. The Origin of Our Species. London: Allen Lane.
- [15] McNabb J, Cole J. 2015. The Mirror Cracked: Symmetry and Refinement in the Acheulean Handaxe. Journal of Archaeological Science Reports 3:100-111.
- [16] McNabb J, Cole J, Hoggard CS. 2018. From Side to Side: Symmetry in Handaxes in the British Lower and Middle Palaeolithic. Journal of Archaeological Science: Reports 17:293-310.
- [17] Solodenko N, Zupancich A, Cesaro SN. 2015. Fat Residue and Use-wear found on Acheulean biface and scraper associated with butchered Elephant Remains at the Site of Revadim, Israel. PLoS One 10:e0118572.
- [18] Yravedra J, Domínguez-Rodrigo M, Santonja M. 2010. Cut Marks on the Middle Pleistocene Elephant Carcass of Aridos 2 (Madrid, Spain). Journal of Archaeological Science 37:2469-2476.
- [19] Keeley LH. 1980. Experimental Determination of Stone Tool Uses. Chicago: University of Chicago Press.
- [20] Mitchell JC. 1996. Studying Biface Butchery at Boxgrove: Roe Deer Butchery with Replica Handaxes. Lithics 16:64-69.

- [21] Binneman JNF, Beaumont P. 1992. Use-Wear Analysis of Two Acheulean Handaxes from Wonderwerk Cave, Northern Cape. *South African Field Archaeology* 1:92-97.
- [22] Dominguez-Rodrigo M, Serrallonga J, Juan-Tresserras J, Alcalá L, Luque L. 2001. Woodworking activities by early humans: a plant residue analysis on Acheulean stone tools from Peninj (Tanzania). *Journal of Human Evolution* 40:289-299.
- [23] Marshall GD, Gamble CG, Roe DA, Dupplaw D. 2002. Acheulian biface database. http://ads.ahds.ac.uk/cfm/bifaces/bf_query.cfm ADS, York.
- [24] McNabb J. 2012. *Dissent with Modification. Human Origins, Palaeolithic Archaeology and Evolutionary Anthropology in Britain 1859-1901*. Oxford: Archaeopress.
- [25] Gamble C, Kruszynski R. 2009. John Evans, Joseph Prestwich and the Stone that Shattered the Time Barrier. *Antiquity* 83:461-475.
- [26] Kuman K. 2007. The Earlier Stone Age in South Africa: Site Context and the Influence of Cave Studies. In: Pickering TR, Schick K, Toth N, editors. *Breathing Life Into Fossils: Taphonomic Studies in Honor of C.K. (Bob) Brain*. Bloomington (Indiana): Stone Age Institute Press. p 181-198.
- [27] Sharon G. 2007. *Acheulean Large Flake Industries. Technology, Chronology, and Significance*. Oxford: British Archaeological Reports International Series 1701. Archaeopress
- [28] Wynn T. 1995. Handaxe enigmas. *World Archaeology* 27:299-322.
- [29] Wynn T. 2002. Archaeology and cognitive evolution. *Behavioural and Brain Sciences* 25:389-437.
- [30] Wynn T, Coolidge F. 2016. Archaeological Insights into Hominin Cognitive Evolution. *Evolutionary Anthropology* 25:200-213.
- [31] McNabb J, Kuman K, Field AS. in prep. The Experimental Knapping Programme at Sterkfontein.
- [32] Wynn T, Gowlett J. 2018. The Handaxe Reconsidered. *Evolutionary Anthropology* 27:21-29.
- [33] Toth N. 1985. The Oldowan Reassessed: A Close Look at Early Stone Artefacts. *Journal of Archaeological Science* 12:101-120.
- [34] Isaac GL. 1977. *Ologesailie: Archaeological Studies of a Middle Pleistocene Lake Basin in Kenya*. London: University of Chicago Press.
- [35] Corbey R, Jagich A, Vaesen K, Collard M. 2016. The Acheulean handaxe: More Like a Bird's Song Than a Beatles' Tune? *Evolutionary Anthropology* 25:6-19.
- [36] O'Connor A. 2007. *Finding Time for the Old Stone Age. A History of Palaeolithic Archaeology and Quaternary Geology in Britain, 1860-1960*. Oxford: Oxford University Press.
- [37] Trigger B. 1989. *A History of Archaeological Thought*. Cambridge: Cambridge University Press.
- [38] Hosfield R, Cole J, McNabb J. 2018. Less of a Bird's Song Than a Hard Rock Ensemble. *Evolutionary Anthropology* 27:9-20.
- [39] Berger A. 2014. *What Objects Mean*. New York: Routledge.
- [40] McNabb J. 1996. 4. Through the Looking Glass: An Historical Perspective on Archaeological Research at Barnfield Pit, Swanscombe, ca.1900-1964. In: Conway B, McNabb J, Ashton N, editors. *Excavations at Barnfield Pit, Swanscombe, 1968 - 1972. Occasional Papers British Museum* 94. London: Trustees of the British Museum. p 31-51.
- [41] Mithen S. 1994. Technology and Society During the Middle Pleistocene: Hominid Group Size, Social Learning and Industrial Variability. *Cambridge Archaeological Journal* 4:3-32.
- [42] Carvalho S, McGrew W. 2012. The Origins of the Oldowan: Why Chimpanzees (*Pan troglodytes*) Still are Good Models for Technological Evolution in Africa. In: Domínguez-Rodrigo M, editor. *Stone Tools and Fossil Bones. Debates in the Archaeology of Human Origins*. Cambridge: Cambridge University Press. p 201-221.
- [43] McGrew W. 1992. *Chimpanzee Material Culture. Implications for Human Evolution*. Cambridge: Cambridge University Press.
- [44] Dunbar R. 1998. The Social Brain Hypothesis. *Evolutionary Anthropology* 6:178-190.
- [45] Hopkinson T, Nowell A, White MJ. 2013. Life Histories, Metapopulation Ecology, and Innovation in the Acheulean. *PalaeoAnthropology* doi:10.4207/PA.2013.ART80:61-76.

- [46] Nowell A, White MJ. 2010. Growing up in the Middle Pleistocene: Life History Strategies and their Relationship to Acheulean Industries. In: Nowell A, Davidson I, editors. *Stone Tools and the Evolution of Human Cognition*. Boulder: University Press of Colorado. p 67-82.
- [47] McNabb J. 2007. *The British Lower Palaeolithic: Stones in Contention*. London: Routledge.
- [48] Pettitt P, White MJ. 2012. *British Palaeolithic: Hominin Societies at the Edge of the Pleistocene World*. Oxford: Routledge.
- [49] Pope M, Roberts M. 2005. Observations on the Relationship Between Palaeolithic Individuals and Artefact Scatters at the Middle Pleistocene Site of Boxgrove, UK. In: Gamble C, Porr M, editors. *The Hominid Individual in Context*. Abingdon: Routledge. p 81-97.
- [50] Roberts MB, Parfitt SA, editors. 1999. *Boxgrove. A Middle Pleistocene Hominid Site at Eartham Quarry, Boxgrove, West Sussex*: English Heritage.
- [51] Hosfield R. 2016. Walking in a Winter Wonderland? Strategies for Early and Middle Pleistocene Survival in Midlatitude Europe. *Current Anthropology* 57(5):653-682.
- [52] Ashton N, McNabb J. 1994. Bifaces in Perspective. In: Ashton N, David A, editors. *Stories in Stone*. Lithic Studies Society Occasional Paper 4. Oxford: The Lithics Studies Society. p 182-191.
- [53] Dunbar R. 2003. The Social Brain: Mind, Language, and Society in Evolutionary Perspective. *Annual Review of Anthropology* 32:163-181.
- [54] Gowlett J, Gamble C, Dunbar R. 2012. Human Evolution and the Archaeology of the Social Brain. *Current Anthropology* 53:693-722.
- [55] Goren-Inbar N, Alperson N, Kislev ME, Simchoni O, Melamed Y, Ben-Nun A, Werker A. 2004. Evidence of hominin control of fire at Gesher Benot Ya'aqov. *Science* 304:725-727.
- [56] Shahack-Gross R, Berna F, Karkanas P, Lemorini C, Gopher A, Barkai R. 2014. Evidence for the Repeated Use of a Central Hearth at Middle Pleistocene (300 ky ago) Qesem Cave, Israel. *Journal of Archaeological Science* 44:12-21.
- [57] Preece RC, Gowlett JAJ, Parfitt SA, Bridgland DR, Lewis SG. 2006. Humans in the Hoxnian: Habitat, Context and Fire Use at Beeches Pit, West Stow, Suffolk, UK. *Journal of Quaternary Science* 21:485-496.
- [58] Gowlett J. 2016. The Discovery of Fire by Humans: a Long and Convolved Process. *Philosophical Transactions of the Royal Society Series B* 371:20150164.
- [59] White M, Plunkett S, editors. 2004. *Miss Layard Excavates: a Palaeolithic Site at Foxhall Road, Ipswich, 1903-1905*. Liverpool: Western Academic and Specialist Press.
- [60] Pope M. 2002. *The Significance of Biface Rich Assemblages: An Examination of Behavioural Controls on Lithic Assemblage Formation in the Lower Palaeolithic*: Unpublished Ph.D thesis. University of Southampton.
- [61] Florent R, Julien M-A, Kuitens M, Van Kolfschoten T, Serangeli J, Drucker DG, Bocherens H, Conard NJ. 2015. Investigation of Equid Paleodiet from Schöningen 13 II-4 Through Dental Wear and Isotopic Analyses: Archaeological Implications. *Journal of Human Evolution* 89:129-137.
- [62] Conway B, McNabb J, Ashton N, editors. 1996. *Excavations at Barnfield Pit, Swanscombe, 1968 - 1972*. Occasional Papers British Museum 94. London: Trustees of the British Museum.
- [63] Stiner MC, Barkai R, A G. 2009. Cooperative Hunting and Meat Sharing 400-200 kya at Qesem Cave, Israel. *PNAS* 106:13207-13212.
- [64] Wenban-Smith F, editor. 2013. *The Ebbsfleet Elephant: Excavations at Southfleet Road, Swanscombe in Advance of High Speed 1, 2003-4*. Oxford Archaeology Monograph, 20. Oxford: Oxford Archaeology.
- [65] Clark JD, Haynes CV. 1969. An Elephant Butchery Site at Mwanganda's Village, Karonga, Malawi and its Relevance for Palaeolithic Archaeology. *World Archaeology* 1:390-411.
- [66] Gallotti R, Raynal JP, Geraads D, Mussi M. 2014. Garba XIII (Melka Kunture, Upper Awash, Ethiopia): A new Acheulean site of the late Lower Pleistocene. *Quaternary International* 343:17-27.
- [67] Hatala KG, Roach NT, Ostrofsky KR, Wunderlich RE, Dingwall HL, Villmoare BA, Green DJ, Harris JWK, Braun DR, Richmond BG. 2016. Footprints Reveal Direct Evidence of Group Behavior and Locomotion in *Homo erectus*. *Nature Scientific Reports* 6:28766 (2016).

- [68] Walker A, Leakey REF, editors. 1993. The Nariokotome *Homo erectus* Skeleton. Cambridge: Harvard University Press.
- [69] McNabb J. 2012. The Importance of Conveying Visual Information in Acheulean Society. The Background to the Visual Display Hypothesis. *Human Origins* 1:1-23.
<http://humanorigins.soton.ac.uk/issues/>. Last accessed 04/04/2015.
- [70] Gèribas N, Mosquera M, Vergès JM. 2010. What Novice Knappers Have to Learn to Become Expert Stone Tool Makers. *Journal of Archaeological Science* 37:2857-2870.
- [71] Stade CM. 2017. Lithic Morphological Variability as a Proxy for Palaeolithic Linguistic Ability: a Knapping Training Study Exploring Cultural Transmission, Theory of Mind and Language: Southampton: Unpublished Ph.D.
- [72] Stout D, Apel J, Commander J, Roberts M. 2014. Late Acheulean technology and cognition at Boxgrove, UK. *Journal of Archaeological Science* 41:576-590.
- [73] Morgan TJH, Uomini NT, Rendell LE, Chouinard-Thuly L, Street SE, Lewis HM, Cross CP, Evans C, Kearney R, de la Torre I and others. 2015. Experimental Evidence for the Co-Evolution of Hominin Tool-Making Teaching and Language. *Nature Communications* 6.6029:DOI: 1038/ncomms7029.
- [74] Miller CA. 2006. Developmental Relations Between Language and Theory of Mind. *American Journal of Speech-Language Pathology* 15:142-154.
- [75] Henrich J. 2016. *The Secret of Our Success*. Princeton, New Jersey: Princeton University Press.
- [76] Dunbar R, Gamble C, Gowlett J. 2014. *Thinking Big. How the Evolution of Social Life Shaped the Human Mind*. London: Thames and Hudson.
- [77] Call J, Tomasello M. 2008. Does the Chimpanzee Have a Theory of Mind. *Trends in Cognitive Sciences* 12:187-192.
- [78] Krupenye C, Kano F, Hirata S, Call J, Tomasello M. 2016. Great Apes Anticipate That Other Individuals Will Act According to False Beliefs. *Science* 354:110-114.
- [79] Kempe M, Lycett SJ, Mesoudi A. 2012. An Experimental Test of the Accumulated Copying Error Model of Cultural Mutation for Acheulean Handaxe Size. *Plos One* 7(11).
- [80] O'Brien E. 1981. The Projectile Capabilities of an Acheulean Handaxe from Olorgesailie. *Current Anthropology* 22:76-79.
- [81] McNabb J. 2004. Reply. *Current Anthropology* 45:673-675.
- [82] Roe DA. 1968. British Lower and Middle Palaeolithic Handaxe Groups. *Proceedings of the Prehistoric Society* 34:1 - 82.
- [83] McNabb J. 2017. Journeys in Space and Time. Assessing the Link Between Acheulean Handaxes and Genetic Explanations. *Journal of Archaeological Science: Reports* 13:403-414.
- [84] Tennie C, Braun DR, L.S. P, McPherron SP. 2016. Chapter 11. The Island Test for Cumulative Culture in the Paleolithic. In: Haidle MN, Conard NJ, Bolus M, editors. *The Nature of Culture: Based on an Interdisciplinary Symposium 'The Nature of Culture'*. Tübingen: Springer Science and Business Media. p 121-133.
- [85] Roe DA. 1981. *The Lower and Middle Palaeolithic Periods in Britain*. London: Routledge and Kegan Paul.
- [86] McNabb J, Sinclair A, editors. 2009. *The Cave of Hearths: Makapan Middle Pleistocene Research Project: Field Research by Anthony Sinclair and Patrick Quinney 1996-2001*. Oxford: University of Southampton Series in Archaeology Number 1. Archaeopress.
- [87] Li H, Kuman K, Leader GM, Couzens RA. 2018. Handaxes in South Africa; Two Case Studies in the Early and Later Acheulean. *Quaternary International* 480:29-42.
- [88] Wojtczak D, Najjar MA, Jagher R, Elsuede H, Wegmüller F, editors. 2017. *Vocation préhistoire. Hommage à Jean-Marie Le Tensorer*. Liège: ERAUL 148 (Etudes et Recherches Archéologiques de l'Université de Liège).
- [89] Mason RJ. 1988. *Cave of Hearths, Makapansgat, Transvaal*. Johannesburg: Archaeological Research Unit Occasional Paper No 21. University of the Witwatersrand.

- [90] Herries A. 2011. A Chronological Perspective on the Acheulian and Its Transition to the Middle Stone Age in Southern Africa: The Question of the Fauresmith. *International Journal of Evolutionary Biology* 2011:Article ID 961401.
- [91] Keller CM. 1973. *Montagu Cave in Prehistory: a Descriptive Analysis*. London: Anthropological Records 28. University of California Press.
- [92] Mercier N, Valladas H. 2003. Reassessment of TL Age Estimates of Burnt Flints from the Paleolithic Site of Tabun Cave, Israel. *Journal of Human Evolution* 45:401-409.
- [93] Ashton N, Lewis SG, Parfitt SA, Penkman KEH, Coope R. 2008. New Evidence for Complex Climate Change in MIS 11 from Hoxne, Suffolk, UK. *Quaternary Science Reviews* 27:625-668.
- [94] White MJ. 2015. 'Dancing to the Rhythms of the Biotidal Zone': Settlement History and Culture History in Middle Pleistocene Britain. In: Coward F, Hosfield R, Pope M, Wenban-Smith F, editors. *Settlement, Society and Cognition in Human Evolution*. Cambridge: Cambridge University Press. p 154-173.
- [95] White MJ, Bridgland DR. 2018. Thresholds in Lithic Technology and Human Behaviour During MIS 9 in Britain. In: Pope M, McNabb J, Gamble C, editors. *Crossing the Human Threshold. Dynamic Transformations and Persistent Places During the Middle Pleistocene*. Abingdon Oxford: Routledge. p 165-191.
- [96] White MJ, Foulds F. 2018. Symmetry is its Own Reward: On the Character and Significance of Acheulean Handaxe Symmetry in the Middle Pleistocene. *Antiquity* 92:304-319.
- [97] Hosfield R, Green CP, editors. 2013. *Quaternary History and Palaeolithic Archaeology in the Axe Valley at Broom, South West England*. Oxford: Oxbow Books.
- [98] Tramacere A, Pievani T, Ferrari PF. 2017. Mirror Neurons in the Tree of Life: Mosaic Evolution, Plasticity and Exaptation of Sensori Motor Matching Responses. *Biological Review of the Cambridge Philosophical Society* 92:1819-1841.
- [99] Rizzolatti G, Sinigaglia C. 2016. The Mirror Mechanism: a Basic Principle of Brain Function. *Nature Reviews Neuroscience* DOI [10.1038/nrn.2016.135](https://doi.org/10.1038/nrn.2016.135).

Figure 1 Cumulative percentages of six UK Middle Pleistocene handaxe assemblages arranged according to outline shape. Outline represents the central 60% of the handaxe (below Roe's B1 and above B2, see Figure 3). There are six basic outlines, concave, straight, convex in the middle part of the handaxe, convex in the lower part of the handaxe. Allocation is by visual appreciation of outline. Two variations are presented, symmetrical and asymmetrical. In the latter the two outline edges clearly belong to the edge shape category designated, but there is no congruence of the two edges either side of a perceived midline. Midlines, outline shape and symmetry are all judged by eye, as would have been the case for the original knapper. In addition two further categories are presented; handaxes which have irregular sides (i.e. do not conform to a clear edge outline shape as above); handaxes which show two different edge shapes (and may include one irregular edge outline). MIS = marine isotope stage; N= is the total handaxe sample used. Data from McNabb ⁷⁹, see that reference for more information. Site details in McNabb ⁴⁷ and Pettitt and White ⁴⁸

Figure 2 A stylised image of a block of lithic raw material that could be knapped into a handaxe. The arrows showing expansion and contraction indicate the potential areas in which a handaxe could increase or decrease its surface area by removing or maintaining area/volume. In effect, this is shape change. The figure is meant to emphasise that shape or outline change is a migration across a zone of limited potential. By increasing the surface area in one part and/or decreasing it in another part, the knapper explores a limited set of potentials imposed on him/her by the physical limits of the block

Figure 3 Measurements and ratios from the system of handaxe analysis developed by Derek Roe ^{80, 83}. The ratios shown here are those used in the PCA analysis. See text for details

Figure 4 PCA conducted in PAST on the three chrono-stratigraphically distinct localities at the Casablanca sequence of Sidi Abderrahman. Dating based on Mercier and Valldas ⁹⁰

Figure 5 PCA conducted in PAST on the three chrono-stratigraphically distinct layers/levels at the Cave of Hearths, South Africa. Layer 3 is the highest and youngest. Dating based on Herries ⁸⁸

Figure 6 PCA on eight British handaxe assemblages conducted in PAST from the Marshall et al. database ²³. Only unbroken examples of handaxes were included in the samples. Variables tested were the Roe ratios from Figure 3

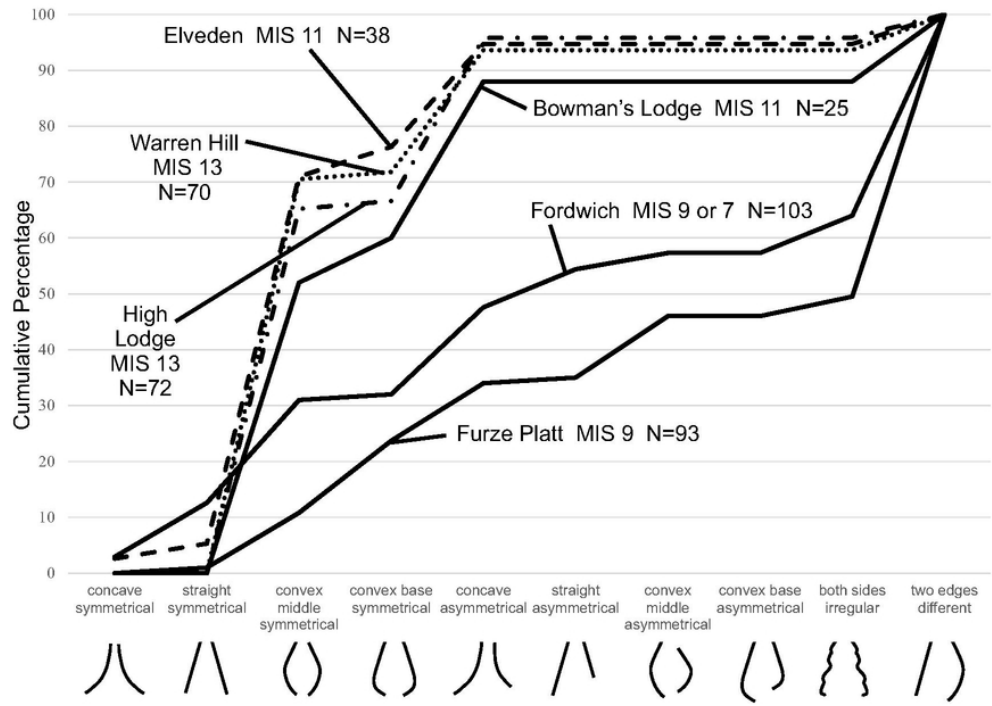


Figure 1

74x52mm (300 x 300 DPI)

	Arguments of Corbey <i>et al.</i>	Responses by the author, and by Hosfield, Cole and McNabb ³⁸
1	A number of current debates surrounding certain aspects of handaxes are described. This serves to establish the handaxe as a highly contested phenomenon concerning which there is little agreement at present.	Presenting handaxes this way serves to downplay those aspects of handaxes which are accepted by most scholars, namely that these are functional objects made to be used, and that they are made and used in a social context.
2	Intergenerational copying errors in the making of material culture are an inevitable consequence of social learning. Studies show a 3-5% error rate over successive iterations. The effects should be cumulative over time. Handaxes ought to show huge diachronic variability, but they don't. So handaxes cannot be a product of social learning.	While the accumulation of copying errors, based on primate observations is not disputed, the experiments which show a 3-5% increase error per generation are unrealistic. What represents a copying error and within what parameters? It seems to assume only one axe per subject per generation. Will not novice knappers improve? Do not master knappers have off-days? How are copying errors to be recognised? What about the 95% of a generation who copy faithfully?
3	Studies on chimps and humans show mixed results in identifying and explaining traditions that occur as a result of social learning. After 40 years there is still no agreement on what really represent chimp social traditions. On the other hand important human behaviours are often not a result of cultural practices.	I have no expertise in the chimp data but there are clearly researchers who are in no doubt that socially learned traditions of behaviour exist in chimp societies. Additionally, the studies quoted which show important human beliefs/practices generated by individual learning (as opposed to social learning) are interesting, but not relevant to the understanding of material culture which is sculpted through long exposure to social experiences; other human behaviours are learnt socially.
4	Culture should not be assumed it should be tested for. Culture is amenable to empirical modelling and such modelling has shown that a) slowly changing environments favour genetic transmission, b) environments with medium rates of change favour cultural transmission of knowledge, c) rapidly changing/unstable environments favour individual learning. If culture/traditions of social knowledge are to persist (i.e. be selected for) then they should track option b).	Corbey <i>et al.</i> readily admit handaxes are found across a variety of environmental circumstances and smaller ecological niches. In this sense they accept handaxes track environments. However their focus on the lack of variability in form leads them, in my opinion, to downplay the importance of the functional argument. Handaxes are large butchery and carcass processing knives, amongst other things. As such they work everywhere and are found in all three types of environment – stable, diverse, and rapidly changing. They are a means of bringing a suitably robust and sustainable cutting edge to a job; they will work anywhere. How do you establish the rate of change at a site?
5	If social learning produces variability through copying errors, and handaxes are found across a range of environments that should promote social solutions, then the lack of variability in handaxes has to be explained by reference to a mechanism other than sociality.	Building on the previous point there may be a number of practical, mechanical and manufacturing constraints that serve to limit the generation of high levels of variety in handaxe form, let alone potential cultural ones - see text. These are not properly engaged with by Corbey <i>et al.</i> Should we really expect endless variability? This needs to be tested realistically.
6	After the Acheulean, the pace and innovative character of cultural change accelerates. Modern humans are able to build sociality and the acceptance of/and learning from strangers into their cultures. Moderns engage in intense distributed culture from a very early age. This contrasts markedly with the nature of cultural interaction by handaxe makers.	Social diversity and richness need not be reflected in material culture or technological sophistication, and Corbey <i>et al.</i> 's perspective may be a biased one. For example, in Europe Levallois is invented by Heidelbergers and Neanderthals, as they develop hafting technology. The latter also invent true laminar technology. These are major innovations. Additionally, the loss of an innovation need not reflect a limited social system or capacity – remember they did invent it in the first place. Moderns (and their cultures) by comparison can often show much more limited outlooks – for example the Aurignacian paucity in burials, grave goods and the attitude towards bodies.
7	A geographical argument based on the appearance of handaxes in China. This section of their argument is somewhat vague. Handaxes appear in Asia long after their first occurrence in Africa, and long after the first appearance of hominins in China. Although not implicitly stated, the argument seems to be that handaxe makers migrated eastwards and gradually lost the knowledge of handaxe making. So, a genetic predisposition to make them is a more parsimonious explanation than the	The argument that the distance between China and the handaxe makers of the west (India) is too great to support migration eastwards, or the maintenance of cultural links, is not logical. Hominins with an Oldowan like technology are in China and island east Asia at c. 1.6 mya. This clearly establishes the potential for successful migration. If Oldowan-like traditions can arrive, so can handaxe ones. Why then are handaxes late in China? They are in eastern peninsular India at 1.5 mya, and in the Bose basin, southern China, at 0.8. mya. Perhaps we haven't found them yet, or


	<p>subsequent arrival of new handaxe makers, or the maintenance of cultural contacts over such vast distances and terrains. Latent sets of genetic action routines are stimulated by an external/environmental trigger; in a densely forested environment the accidental exposure of suitable raw materials initiates a return to handaxe making.</p>	<p>their movement eastwards was genuinely later. In either case it behoves the geneticists to explain why their environmental triggers fired so infrequently, and why no earlier? Corbey et al. do acknowledge the possibility of convergent evolution, but find their genetic explanation more parsimonious. But in this argument which is more parsimonious, a latent trait dormant for millennia suddenly becoming active when a stimulus presents itself, or a long hominin knapping tradition of bifacial core flaking, incorporating alternate flaking and discoidal cores, giving rise to a similar type of edge but now on an elongated cutting tool?</p>
8	<p>Neuroscience supports a link between pre-programmed action sequences and complex hierarchically organised expressions like language and tool manufacture through similarities in the way they are expressed neurologically. The same part of the brain controls both and there is direct genetic control for language acquisition at least. Essentially the argument is - what wires together fires together. Tool making, handaxes and language could therefore easily have a common genetic origin.</p>	<p>Wynn and Gowlett (2018) posit the presence of a straightforward ‘anthropoid object manipulation network’, an ancient neural pathway that successfully links object manipulation with goal direction. The need for a large cutting tool and the pre-existence of the pathway are sufficient to explain handaxes. Predetermined instruction sets, under genetic control are not necessary. Passing through the parts of the brain associated with language could merely add the capacity for hierarchical nesting of action sequences. This still would not require a direct genetic control.</p> <p>The counter argument to Corbey et al., irrespective of the specifics, is that ancient neurological pathways can explain the complexity of handaxe making. Structures such as the mirror neuron system that set up empathic responses when tool making is observed could enhance neurological as opposed to genetic explanations (e.g. intensify the experience of social learning via imitation). Experimental work on ape goal comprehension ⁷⁷⁷⁸ and gaze direction (together with the MNS) demonstrates many of the pre-requisites necessary for tool making/manipulation in the absence of language.</p>
9	<p>If a genetic basis to handaxe making is accepted, then two interpretations are possible.</p> <ul style="list-style-type: none"> a) Soft genetic approach. This is embedded in the dual inheritance theory of gene-culture co-evolution. The basic designs, themes and sequences of manufacture are genetic, however role models and social learning fine tune the details and produce variations on the basic theme. This option incorporates some conscious capacities on the part of the knapper. b) Hard genetic approach. No cultural input at all. Hominins follow pre-programmed instruction sets under genetic control which are triggered by external stimuli. The complicated structures of Bower Birds and other birds are emergent properties of these instruction sets and their sequence of expression. This option implies no conscious ability to modify process of manufacture or its end result. 	<p>Corbey et al. prefer option a). Response here is as above.</p>
10	<p>Although like handaxes, cleavers may also be under genetic control, some other tool forms may not be because not all human behaviours need to be influenced by the same mechanisms (point 3 above).</p>	<p>This does not engage with the idea of the Acheulean package – large flake blanks with the preparation of cores or boulders to produce blanks. Why should handaxes and cleavers have a genetic control but picks and knives not? Why would the complicated production of a pre-prepared</p>

		blank be social but the concept and actuality of a handaxe be genetic? This is not just fine tuning in the sense of option 9a) above – this is a fundamental part of the process.
--	--	---

Table 1 The table takes ten points which are important in Corbey et al.'s construction of a genetic predisposition to handaxe making and shows how most are more parsimoniously explained by a social interpretation.

Text box 1. Methodological concerns, or, put another way, what would a copying error on a handaxe really look like?

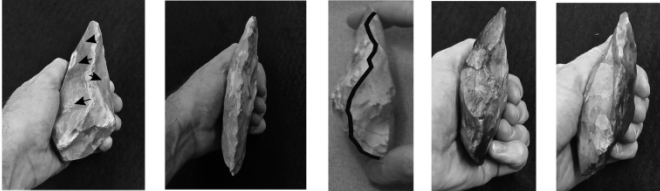
Shape?



What would a bad copy of each of these basic shapes look like, or of any of the outlines in Figure 1. How or why would you recognise them as being 'errors', as opposed to natural variability, perhaps as a result of differing knapping abilities?

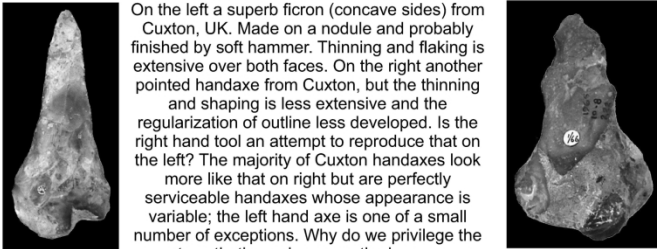
Edge character?

Here are three different kinds of edge; scalloped and sinuous made by single alternate flake removals with a hard hammer; straight (or slightly sinuous) made by multiple bifacial thinning and shaping flakes with a hard or soft hammer, and an S twist made by multiple bifacial removals. Many handaxes have a mixture of the first two. Whether these edge types are made for different jobs is unknown, but what would a miss-copy look like? The crunched edges of modern beginners are not common in archaeological assemblages of handaxes (pers. obsv.). The crushing and scalloping on the fourth image would at first seem like poor copying or manufacture. In fact it is accommodation retouch to remove the butt of the flake blank. The opposite edge is a perfectly serviceable unifacial cutting edge - fifth image.



scalloped straight S twist crushed & scalloped opposite (cutting) edge

Errors in replicating the process of manufacture?



On the left a superb ficron (concave sides) from Cuxton, UK. Made on a nodule and probably finished by soft hammer. Thinning and flaking is extensive over both faces. On the right another pointed handaxe from Cuxton, but the thinning and shaping is less extensive and the regularization of outline less developed. Is the right hand tool an attempt to reproduce that on the left? The majority of Cuxton handaxes look more like that on right but are perfectly serviceable handaxes whose appearance is variable; the left hand axe is one of a small number of exceptions. Why do we privilege the most aesthetic, and assume the less so are imperfect? Images from Marshall et al.

Note to editor - This is a text box

171x276mm (300 x 300 DPI)

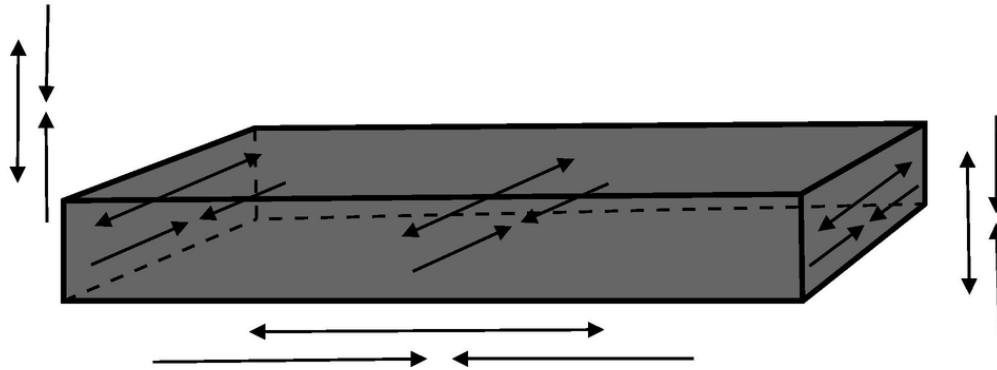


Figure 2

80x29mm (300 x 300 DPI)

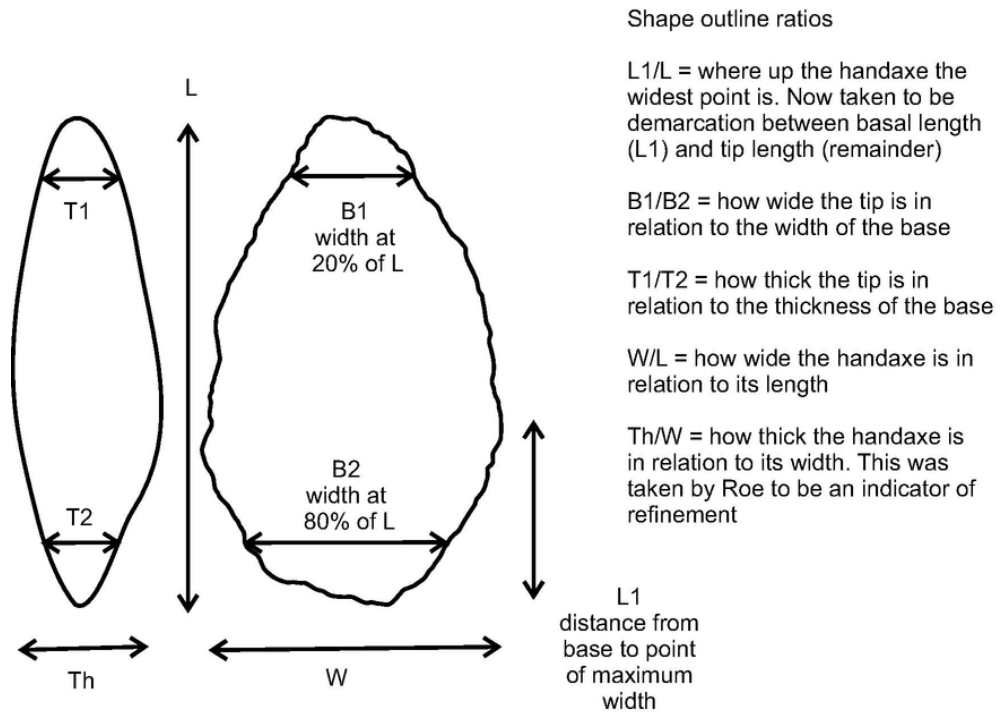


Figure 3

74x53mm (300 x 300 DPI)

Cunette (Cap Chatalier), grey circles, N = 135, c. 367 kya/MIS 11/10

Grotte des Ours, black squares, N = 40, MIS 12/11

STIC Quarry, open triangles, N = 79, c. 492 kya/MIS 13 and on artefact typology

MANOVA on Roe ratios shows statistically significant differences between all three assemblages (Wilks' lambda 0.5487, $df_1=10$, $df_2=494$, $F=17.29$, p =considerably smaller than <0.01)

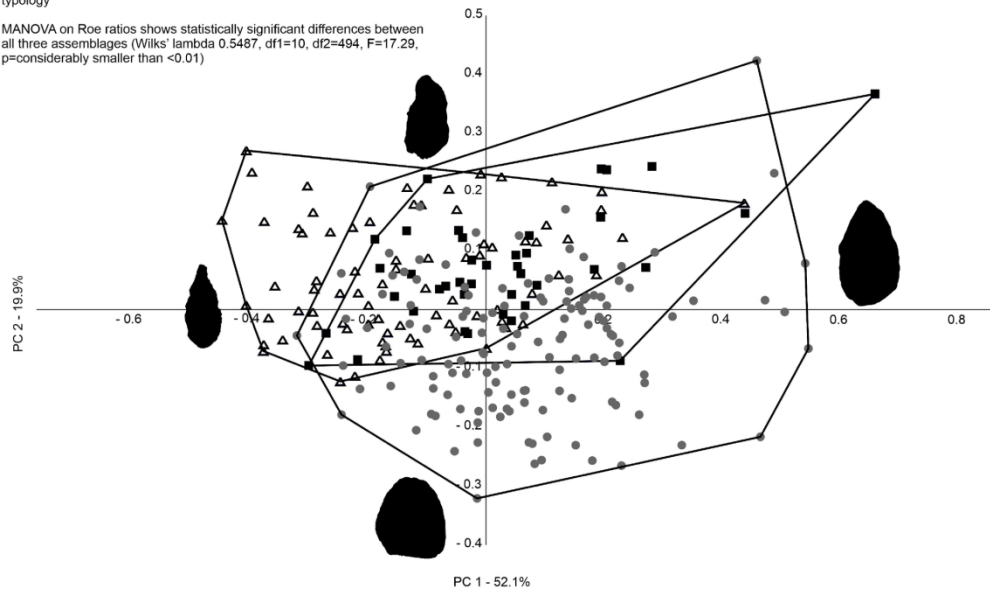


Figure 4

180x123mm (300 x 300 DPI)

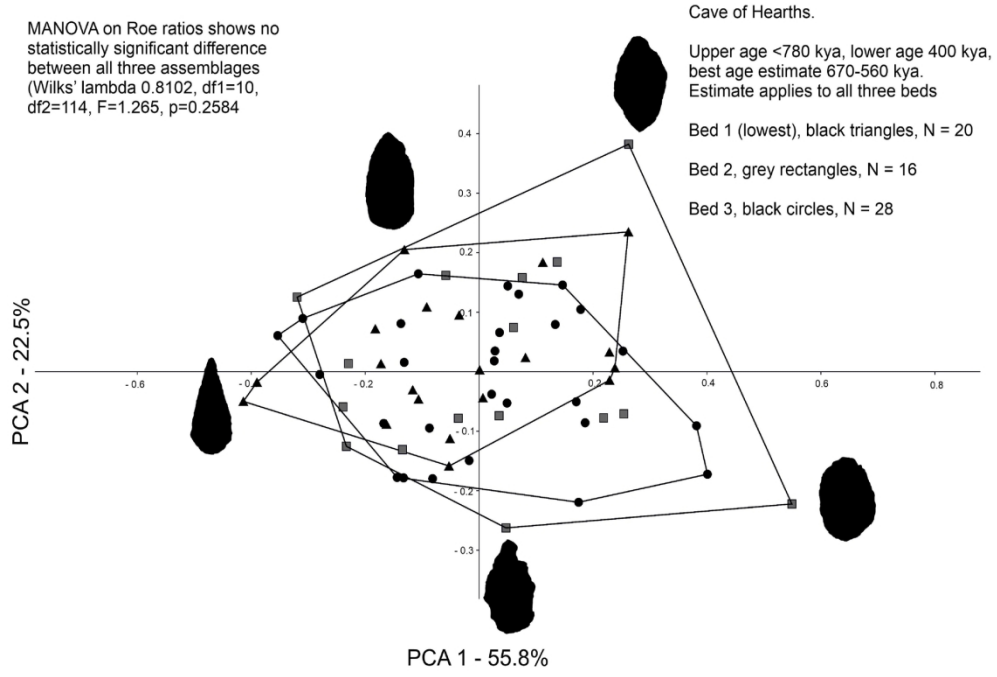


Figure 5

177x119mm (300 x 300 DPI)

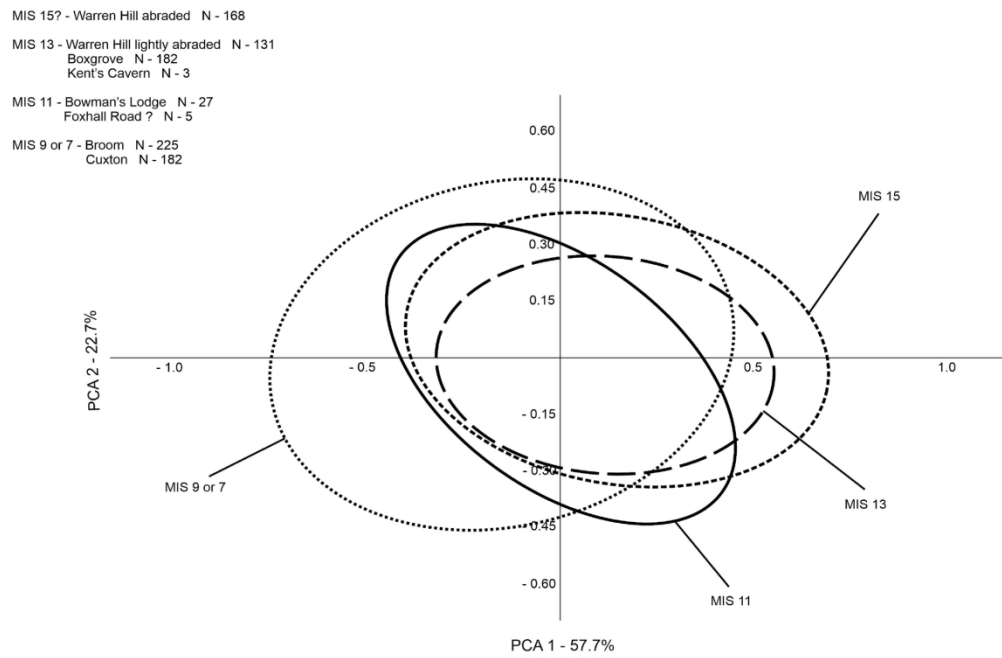


Figure 6

178x120mm (300 x 300 DPI)