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Evolution and Human Cognition

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Abstract. There can be no reasonable doubt that our living species Homo sapiens is fully integrated into the great Tree of Life that unites all living organisms on this planet. But it is also obvious that we are not just another run-of-the mill primate. But what distinguishes us most strongly from those relatives – and all other organisms – is something more abstract: the unusual and unprecedented way in which we process information in our minds. That is not so in our case, and a useful shorthand descriptor of the difference between us and them is that we think symbolically. In other words, we mentally deconstruct our exterior and interior worlds into a vocabulary of discrete symbols and then rearrange them, according to rules, to describe those worlds not only as they are, but as they might be.

Keywords. Evolution; Human Cognition; Symbol.

There can be no reasonable doubt that our living species *Homo sapiens* is fully integrated into the great Tree of Life that unites all living organisms on this planet. But it is also obvious that we are not just another run-of-the-mill primate. There is, after all, a long list of physical features differentiating us even from our closest living relatives, the African apes, most of them relating in one way or another to our unusual bipedal form of locomotion. But what distinguishes us most strongly from those relatives – and all other organisms – is something more abstract: the unusual and unprecedented way in which we process information in our minds. The great apes are highly intelligent beings, who nonetheless react more or less directly to their environments, albeit sometimes in remarkably sophisticated ways (Cohen [2010]). They live essentially in the world as Nature presents itself to them. Not clear that is not so in our case, and a useful shorthand descriptor of the difference between us and them is that we think *symbolically*. In other words, we mentally deconstruct our exterior and interior worlds into a vocabulary of discrete symbols and then rearrange them, according to rules, to describe those worlds not only as they are, but as they *might* be. And as a result of this, we actually live for much of the time less in the "real" world than in the worlds we individually reconstruct within our heads.

This is not, of course, to suggest that the cognitive processes of primates and other vertebrates cannot be very complex indeed. For example, apes can readily recognize and respond to symbols, both visual and verbal. And they can even use them additively, to make and understand simple statements, such «take … red … ball … outside». But this basic additive treatment of symbols is hugely limiting; and what apes evidently do not is to engender multiple alternatives by rearranging such symbols in the human fashion. And as a result, there is a narrow but hugely significant gulf between the cognitive styles of human beings and all other organisms.

Nonetheless, given our deeply embedded position within the Tree of Life, there can be no rational doubt that our symbolic and linguistic species *Homo sapiens* was descended from an ancestor that was neither of these things. Which means that, at some point in our evolution, the symbolic and linguistic gulf *must* have been bridged. This is an almost unimaginable event; and it is hardly surprising that, while many have pondered upon how this bridging was achieved, resulting conclusions have diverged greatly. Some scientists have concluded that such attributes as language and symbolic cognition are so complex and deeply ingrained in our species that their roots must extend far back in time (Pinker, Bloom [1990]). Others alternatively believe that they are "either/or" traits that probably originated in short-term events (e.g. Berwick and Chomsky [2016]). The implications of these two scenarios are not only starkly different, but they are hugely consequential for our ideas of who we are as a species. The gradualist viewpoint implies that our behavioral features have been slowly honed by natural selection over the eons and are thus deeply encoded within us, making us to a significant extent the behavioral prisoners of our biological heritage. In sharp contrast, the sudden-origin notion eliminates natural selection as a driving force in the origin of the unique modern human form of consciousness, thereby admitting the possibility that there were elements of chance in our becoming what we are. If this view is correct, it is more probable that our behaviors are not closely channeled by our genetic heritage, and that we possess a significant latitude in our behavioral repertoire.

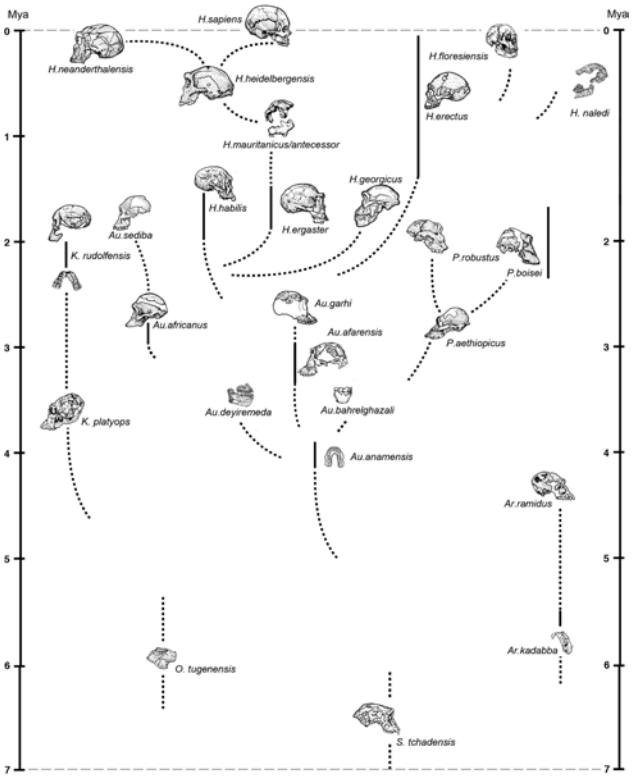

Figure 1. Outline schema of hominid evolution, showing that several hominid species typically coexisted at any one point in time; it is *Homo sapiens* that is highly unusual in being the only hominid on the planet. Drawn by Kayla Younkin.

In choosing between these options, only empirical evidence will help. And, since cognition itself obviously does not preserve directly and such factors as the brain sizes and external morphologies of our extinct fossil relatives have proven rather disappointing in this respect (Tattersall [2012]), we have only two places to look for such evidence. One of these is the overall pattern of human evolution, which is reflected in the family tree given in Figure 1. This might be expected to show a basically linear form if our evolution had been dominated by steady within-lineage natural selection, whereas more adventitious influences would be expected to produce a bushier profile. And as the figure shows, this highly speciose tree shows a vigorously branching pattern in which

numerous hominid species were evidently spun off to do battle in the ecological arena, with both their relatives and more distantly related competitors, and to succeed or more likely fail. The pattern is one of diversity. It shows active experimentation with the hominid potential, rather than the smooth and gradual change that might be expected from improvement via within-lineage selection.

The second source of information on evolutionary process is the archaeological record, the direct if sometimes rather murky material register of ancient hominid behaviors. For the Pleistocene epoch, roughly the two million years over which our genus *Homo* evolved, this record is pretty limited, consisting for the most part of stone tools and butchered animal bones, and of the ways in which those elements are spatially disposed at occupation sites. And although technological indicators of this kind may in the aggregate be indicative of general complexities of lifestyle, it is hard to argue that any of them is a good proxy for any specifiable cognitive condition – which is one major reason for the disputes already alluded to. Still, while many Paleolithic stone-working techniques are certainly witness to very sophisticated cognitive states, it seems pretty evident that few of them, if any, can be used in isolation to infer the specifically modern human symbolic cognitive style: something that may be particularly relevant in light of the fact that learning by imitation can extend to some extremely complex processes indeed. And this, for the most part, leaves us only with explicitly symbolic artifacts as reliable proxies for the specifically modern symbolic cognitive style.

But then again, opinions may legitimately differ as to what might or might not be considered a symbolic artifact. Can we consider as symbolic a roughly-altered lump of stone that looks vaguely anthropomorphic to a modern observer? Were colored gastropod shells, presumptively pierced for stringing, necessarily part of a symbolic ornamentation system? Does the simple presence of ground ochre in archaeological deposits necessarily imply that this functionally-useful pigment was also used for symbolic bodily decoration? There will always be difficult cases like these, but fortunately certain early expressions were more overtly symbolic. Such expressions include the realistic animal representations that began to be produced around 40 thousand years ago, by artists who were clearly our cognitive peers. Perhaps even more importantly, symbolic thought allows hominids with clever hands not only to remake the world in their minds, but to shape the world around them to conform to what they have imagined. Symbolic *Homo sapiens* has transformed the landscape in a remarkably short lapse of time, and if any other hominid lineages had possessed this ability, we should surely expect to find it expressed in some visible inflection in the archaeological record.

Given all this, it seems worthwhile to look briefly back over the long record of the hominid family, to see at what point in human evolution we are able to reasonably infer the possession of modern symbolic behaviors. To begin at the beginning, long before we have any archaeological record to hand, the earliest probable hominids consist of a handful of generally poorly-known and rather ill-assorted African forms, between about 7 and 4 million years (myr) old, all of which owe their hominid status largely to claims that they were upright bipeds when they moved on the ground. Much better documented are the so-called "australopiths" of between about 4 and 1.5 myr ago. These relatively diminutive and short-legged human precursors were clearly bipedal on the ground, but they also retained numerous features of the skeleton indicating that they were agile in the trees. Their brains were slightly larger than those of the living apes and the earliest hominids, but they were still small, and they had large chewing teeth housed in protruding faces. Not for nothing have the australopiths sometimes been called "bipedal apes". Still, from the very beginning they seem to have shown different ecological preferences from today's apes, exploiting a much wider range of resources in the expanding Plio-Pleistocene African woodlands and bushlands.

By around 3.4 myr ago there are already hints that early hominids had begun to use sharp stone flakes to butcher mammal carcasses; but deliber-

ately-made stone tools actually begin to show up rather later, at sites in Kenya and Ethiopia dating from about 2.6 myr ago. And it is with these simple implements, small cutting flakes bashed from one small cobble using another, that we have the first definitive evidence that hominids had moved cognitively well beyond the ape league. Still, despite this radically new behavior, the earliest stone tool makers seem anatomically to have been standard-issue australopiths. And this gives us the first indication of another significant pattern we find repeated throughout the hominid record. Namely, that new kinds of technology tend not to be introduced by new kinds of hominid: as far as innovation is concerned, the archaeological and fossil records are clearly out of phase.

This certainly held true for the earliest well-characterized members of our genus *Homo*, whose fossils begin to be found in Africa at sites a little under 2 myr old. For, as physically advanced as they may have been, these hominids of the species *Homo ergaster* appeared in association with simple flake tools identical to the ones their predecessors had already been making for half a million years. Still, in other ways, they were indeed radically new creatures: tall, slender, long-legged, and with significantly expanded brains. Physically, they were adapted for life in the expanding bushlands of the time, far from the protection of the forest. And for energetic reasons it is reasonable to conclude that they had already assumed an at least partly predatory way of life.

Once more, it took a while before the new hominids started regularly to manufacture a new kind of implement: the large and bifacially-flaked "handaxe" that was made to a predetermined form and that became common at about 1.5 myr ago. What is more, although several kinds of *Homo* apparently came and went in the intervening period, it was not until over a million years after the introduction of the handaxe that a conceptually new kind of stone tool began to be regularly used. This was the so-called "prepared-core" tool in which a stone nucleus was elaborately worked on both sides until a final blow, or blows, would detach a more or less finished implement. And, once again, these conceptually more complex tools appeared well *within* the tenure of an existing species, in this case the world's first cosmopolitan hominid, *Homo heidelbergensis*. This hominid appeared in both Africa and Europe at about 600 thousand years (kyr) ago, and it boasted a brain only slightly smaller than that of today's *Homo sapiens*. Within its time span several other radical technological innovations were also introduced, among them the hafting of stone tools, the construction of artificial shelters, the regular domestication of fire, and the first finely-shaped wooden throwing spears. But significantly, virtually nothing produced during its tenure is uncontestably symbolic. The clear message of *Homo heidelbergensis* is that a hominid can be resourceful, smart, behaviorally flexible, and technologically sophisticated in the absence of symbolic reasoning, or at least of any deeply embedded inclination to express this cognitive style (Tattersall [2012]).

We can also say more or less the same thing for *Homo neanderthalensis*, which evolved from indigenous European predecessors at about 200 kyr ago. The Neanderthals had brains as big as ours, they were wonderful craftsmen in stone, and they left us an incomparable record of very complex lives. They flourished in an age of difficult climates; they hunted some fearsomely large animals; and, at least occasionally, they buried their dead. There is even genomic evidence of occasional interbreeding with *Homo sapiens* (Green et al. [2010]), although there is actually nothing surprising about interbreeding among very close relatives. But despite some equivocal and disputed expressions mostly in very late times, the Neanderthals bequeathed us very little convincing evidence of any consistent tradition of symbolic activity. And in a record as geographically, temporally, and materially as expansive as theirs is, if the Neanderthals *had* been symbolic thinkers, they would surely have left us more convincing indications of this fact. Of course, to say this is not to disparage the Neanderthals in any way. Clearly, these were complex and sophisticated beings, clever exploiters of their environments. Nonetheless, it is hard to avoid the impression that they interacted with the world around them very differently from

the way in which *Homo sapiens* typically does.

Perhaps even more amazingly, the same identical thing also appears to have held for the earliest fossil representatives of our very anatomically distinctive species *Homo sapiens.* Fossils showing substantially modern morphologies have been found at Ethiopian sites dating between about 200 and 160 kyr ago. And those early anatomically modern humans are associated with some notably archaic toolkits. Now obviously, members of our species eventually began to reason symbolically, or we wouldn't be discussing the issue today. But it is not until around 100 kyr ago that we start finding the first plausible indications of this unprecedented cognitive style. And again, those indications first show up in Africa and nearby. At about this time, pierced marine shell beads and ochre deposits start to show up at sites around the Mediterranean and in South Africa (Bouzouggar et al. [2017], d'Errico et al. [2009], Henshilwood et al. [2011]). Such objects may on their own be arguable as indicators of modern cognition. But they are soon supplemented by more direct evidence, the best of which comes from Middle Stone Age (100-70 kyr-old) occupation strata at Blombos Cave, on the southern African coast. This evidence consists of smoothed ochre plaques engraved with geometric designs, the best of which dates from some 77 kyr ago (Henshilwood et al. [2002]).

Hominid fossils are sparse at MSA sites, but the evidence overwhelmingly suggests that these early expressions of behavioral modernity in South Africa were the work of members of our own anatomically distinctive species *Homo sapiens.* And, as a result of this evidence, a fairly firm scenario of modern human origins and geographical dispersion is emerging. What seems to have happened is that *Homo sapiens* appeared as a distinctive anatomical entity in Africa at about 200 kyr ago. At first, members of the new species behaved much as had their predecessors and hominid contemporaries. But at around 100 kyr ago they began to show new and unprecedented behavioral tendencies that included the production of symbolic objects. And very soon after that, populations descended from those first symbolic humans exited Africa and rapidly took over the world. Earlier, non-symbolic *Homo sapiens* had forayed into the Levant without displacing the resident Neanderthals, or even gaining a lasting foothold. But these later symbolic emigrants from Africa clearly had a cognitive edge that allowed them rapidly to displace the hominid competition throughout Eurasia. From *Homo erectus* in the Far East, to *Homo neanderthalensis* in the far west, all hominid competitors promptly disappeared.

In the best-documented case of early behaviorally modern penetration of remote Eurasian regions, the dazzling tradition of European cave decoration had already begun by around 40 kyr ago, accompanied by an amazing record of musical instruments, notations, portable art, and evidence of unprecedentedly sophisticated economic strategies. What's more, animal images have now been dated to around 40 kyr ago in Sulawesi and Borneo, suggesting that the tradition of representational art in Europe and Asia had originated earlier yet. The most plausible place of origin is Africa, and the timing would have been soon after the emergence there of symbolic cognition.

Of course, human beings are complex creatures descended from complex precursors. And occasionally we do find unusual expressions in the record those precursors left. For example, half a million years ago someone incised a zig-zag pattern on a mollusk shell found in Java, in putative association with *Homo erectus* (Joordens et al. [2014]). At the other end of the timescale, a deep hash engraving was found in a site were very late Neanderthals had lived (Rodriguez-Vidal et al. [2014]). But one swallow (or even two) doesn't make a summer; and, while intriguing, these items and a small handful of others are floating points that were not embedded in any identifiable symbolic tradition. Whereas, in dramatic contrast, the entire tenor of human life was clearly and dramatically changing among *Homo sapiens* in the later African Middle Stone Age, adding up to a fundamental behavioral transformation that sparked a revolution in the way in which hominids did business in the world. Previously, hominids had met

environmental challenges by adapting old technologies to new purposes, rather than by inventing new ones. Hence the typical stasis in stone tool kits. But with the emergence of behaviorally modern *Homo sapiens* a totally unprecedented entity was on the scene: one that clearly possessed the very same restless appetite for change that increasingly dominates our own lives today.

So, how do we explain the rapid emergence of this extraordinary and basically unprecedented new neophile phenomenon? Virtually overnight in evolutionary terms, human beings were behaving in an entirely unprecedented new way; and it was clearly not long-term natural selection that precipitated a sudden event that, moreover, clearly took place *within* an existing species. Further, the acquisition concerned was a behavioral one; and that such a behavioral event could have taken place at all can only be explained by the recruitment of neural systems that already happened to be in place. So how and when might those systems have been exaptively acquired? The only obvious possibility is the radical developmental reorganization that resulted, some 200 kyr ago, in the highly derived skeletal anatomy of the new species *Homo sapiens*. The genetic alteration involved in this event was almost certainly a rather minor one at the molecular level (likely involving changes in gene expression rather than in the protein-coding genome itself), but it evidently had cascading developmental consequences throughout the body; and there is no reason to believe that those consequences should necessarily have been confined to the skeletal and dental systems which are all that the fossil record preserves.

Still, the lag in the archaeological record indicates that the new cognitive potential lay fallow for a short but significant time. During this time, anatomical *Homo sapiens* continued to behave in the old manner, producing an unremarkable archaeological record. But then something happened to stimulate the recruitment of the new behavioral potential inherent in an adventitiously rewired brain, much as ancestral birds rather tardily discovered that they could use their feathers to fly. So what might the necessarily purely cultural stimulus for this change have been? By far the most plausible candidate we have is the spontaneous invention of language, which several factors combine to make particularly attractive in this role. First, language is the ultimate symbolic activity. Indeed, from our modern perspective it is virtually impossible to imagine thought in isolation from language. The linguist Wolfram Hinzen has, for example, recently recalled that the «close connection between grammar and thought» was a consistent theme in early studies of generative grammar, and he has provided persuasive arguments for reviving the view not only that language and thought are «not two independent domains of inquiry», but that thought itself is inherently grammatical. In other words, among modern people language and thought are so closely intertwined that they appear functionally, if not conceptually, inseparable.

In terms of interpreting the material archaeological record one can of course object that, while all human beings are symbolic, they do not all necessarily leave traces of this proclivity in objects that might be preserved. But over the long haul, and over the entire expanse of its distribution, we would surely expect any species that processed information in the modern human manner to have left some consistent material indication of its unusual cognitive status, just as we ourselves have so dramatically done in recent millennia. And we simply do not find anything equivalent in the case of any extinct hominid species, even the big-brained and well-documented Neanderthals.

Significantly, there is no reason to question the notion that the invention of language by a biologically predisposed hominid might have been a more or less instantaneous event. On a theoretical level, for example, Noam Chomsky and his colleagues have recently argued that the algorithmic basis of language is extremely simple (Berwick, Chomsky [2016]), so that an "either/or" switch is highly likely, much as in the case of the structured sign language observed to emerge virtually instantly among a community of deaf but "language-ready" children in Nicaragua (Senghas et al. [2005]). This property of suddenness not only

makes language a particularly credible driver of symbolic reasoning, but also distinguishes it from such rival stimulants of symbolic thought as theory of mind, which all demand long-term directional selection. Just as importantly, language is not only a portal to thought but is an externalized attribute that would have been poised to spread rapidly within a population that was already biologically-enabled for it.

In the scenario envisaged here, language and symbolic thought are inextricably intertwined. And the two were more or less simultaneously acquired by *Homo sapiens* in a single, short-term feedback event – an event that was both recent and emergent.

And it was *ex*aptive, rather than *ad*aptive. It was a randomly occurring event, rather than one driven by eons of natural selection. Exaptation is the routine evolutionary process whereby novelties arise in contexts entirely other than the ones in which they will eventually be co-opted. And neatly, this very same evolutionary mechanism also explains how the highly derived modern vocal tract needed to produce articulate speech was in place at precisely the point when it was needed for the expression of language – having originated as no more than an incidental byproduct of the retraction of the face beneath the braincase that is the most fundamental cranial specialization of *Homo sapiens*. Interestingly, this renders the long-running argument over the condition of the larynx and various other structures of the upper vocal tract in fossil hominids irrelevant to the precise point in human history at which language was acquired. The vocal tract simply happened to be there first, as of course it had to be.

The notion that the human brain recently underwent a recent and sudden algorithmic shift, a radical change in the way in which it worked, is supported by the rather counter-intuitive fact that, after two million years of steady expansion, our brains have apparently shrunk significantly since the end of the last Ice Age, some 10 kyr ago.

Both the Neanderthals and the early modern European *Homo sapiens* who replaced them some 40 to 30 kyr ago seem to have had brains of approximately equal volume, making both almost 13 percent bigger than the brains of people today. And, especially because brain is metabolically a very costly tissue, this fact strongly suggests that the ancestral intuitive brain operated on a "brute-force" algorithm, in which "intelligence" scaled more or less directly with brain volume (Tattersall [2017]). In contrast, the new symbolic algorithm proved to be a much more metabolically frugal one, demanding less energy input to produce an emergently different cognitive product: a product that made its possessors significantly more effective in the competition for ecological space than any hominid that had previously existed. And hence our lonely status as the only hominid in the world today.

All this having been said, we unquestionably share vastly more similarities with our closest ape relatives than we show differences from them. And, for all its peculiarities, our cognitive style is clearly built upon a long and complex series of acquisitions over almost half a billion years of vertebrate brain evolution. Yet our unique mode of information processing was clearly acquired amazingly recently, in an abrupt and emergent event that was entirely random with respect to adaptation. And that, in turn, strongly suggests that we human beings as we are today have not been programmed by eons of evolution to behave in specific ways, as some scientists like to suggest. The algorithmic change shifted all the rules by which humans play the evolutionary and cognitive games, allowing us to stand back and rationally appraise the situations in which we find ourselves. Knowing that the rules themselves have changed is incredibly important, because it helps us to understand a lot about our condition, why it differs from those of other organisms, and why it is so difficult to pin down. For we are optimized for nothing, and thereby not condemned to be anything. The fact that we can envisage alternatives makes all those alternatives at least conceptually available to us, and it gives us an astonishing latitude in the behaviors we exhibit. Our genotypes may incline us to respond in particular ways to the situations we find ourselves in, but we nonetheless have free

will to the extent to which we are consciously able to modify those responses. And that also endows us with a peculiar kind of responsibility: one that, sadly, it is all too easy to ignore.

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