

In the beginning was... the monkey!

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Introduction

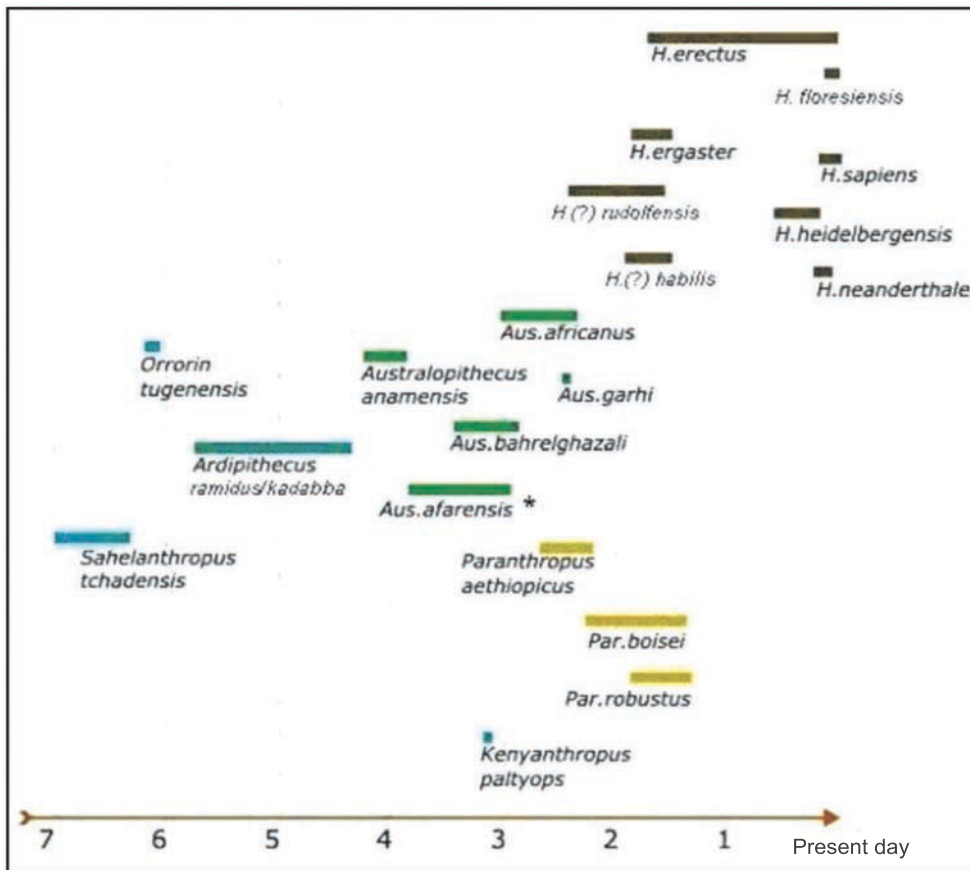
AS I WILL ATTEMPT to show in this article, we already know a lot about the evolution of our line, the hominins^a (Figure 1). Moreover, I will try to demonstrate how it is beyond all doubt that we are, like all other creatures on the planet, the product of a natural process of modification over time; in our case, beginning with a great ape. In other words, I will attempt to convince the reader, as didactically as I can, that man did indeed inexorably derive from the ape, albeit by the most tortuous of paths.

No less true, however, is that a great deal remains to be learnt about the details of this process and about how we came to be what we are. Decades of field and laboratory study will be needed before the scientific community can present the world, inside and outside of academia, with a detailed map of what happened to us and to our ancestors over the course of the last seven million years since our evolutionary line split from the common ancestor we shared with the chimpanzee.

It is always worth recalling that the modern chimpanzee is the result of a seven-million year evolutionary process of its own. Proof of this is the fact that, 2.5 million years ago, a common line of chimpanzees gave rise to an offshoot, still with us today, called the bonobo or pygmy chimp.

For those who, like myself, dedicate their lives to the study of human evolution, it is not unusual to hear colleagues and students declare in the hallways and corridors of academia that all it will take is for one new fossil to turn up somewhere in Africa and everything we know about our ancestors will be changed forever. However frequent it may be, I will also try to show in this article that the declaration does not correspond to the reality. Of course, with each new fossil find our theoretical models become more precise, edging that little closer to the real story, just as happens in all fields of scientific knowledge.

However, before going any further, I would first like to underscore something rarely stressed by scientists in general and which, in my opinion, creates unrealistic expectations about us, namely that Science is not infallible! Otherwise put, the epistemological superiority of western science vis-à-vis other forms of knowledge production should not be sought in the scorecard



* Also classified as *Praeanthropus africanus*.

Figure 1 – Distribution over time (in millions of years) and possible phylogenetic tree showing the main evolutionary branches in hominin evolution.

of its hits and misses. That superiority or precedence rests upon what would normally seem the Achilles heel of any system of systematic reflection: the possibility of error, in other words, its fallibility!

Embarking from the principle that any systematic exercise in reflection, based or not upon empirical data, is subject to error, western science, right from the outset, worked into its operational process a fabulous self-correction mechanism: it generates its knowledge from experiments or from the observation of natural experience in such a way as that same exercise, that very track, can be retraced step-by-step by any other scientist interested in the same subject, allowing he or she to agree or not with the results and/or conclusions of the original experiment.

The name given to this is replicability. In other words, the difference between we scientists and other knowledge producers is that we work in such a way as enables others to check our experiments and conclusions, replicating them, sometimes wholly refuting or verifying them, or sometimes just fine-

tuning the theories drawn from them. This is what René Descartes, one of the precursors of modern science, referred to as “provisional morals”. Another factor that distinguishes Science from other forms of knowledge production is that it can only be applied to natural phenomena.

This might not seem like much to some, but similar or better quality control mechanisms are not even considered by other knowledge-production strategies, mainly metaphysical in nature, which is why in direct comparison with other available systems for reflection upon the natural world, science must certainly prevail.

In other words, the pillars of Science are, on the whole, provisional morals, and it is by shaping and polishing those provisional morals that we move closer and closer to the reality, to the real processes at work in nature, and which we hope to evince, understand and, if possible, manipulate.

Put another way, scientific procedure allows us to reach increasingly deeper and subtler layers of reality. Yet, it is not always necessary to plumb those depths in order to understand, explain and manipulate natural processes. If this were not the case, we could never have attained the levels of technological development at our disposal today. We flick the switch on the wall and the light turns on above us on the ceiling, we take an aspirin and our headache fades after just a few minutes...

Briefly put, our provisional morals, however provisional they may be, cannot be too far removed from the reality of how things actually work, otherwise we would still be chipping flints and worshipping meteorological phenomena like they were gods.

I wanted to start my article with this little digression on how western science really works in order to set a favourable intellectual environment for the real point I want to reach. There is a common saying among the lay-folk that goes: biological evolution is not a fact, but a theory. And as it is “just” a theory, there’s no need to take it seriously. Sweet illusion! Theory is, indeed, the most noble and superior rung of systematic formulation in any natural science, and, what is more, scientific explanation is precisely that; explanation, not fact.

In the academic world, the word theory does not have the same connotation it carries in colloquial usage. We can often hear people say things like “Ah, in theory...” or “Theoretically”, when speaking of future, run of the mill events, expressions that denote a certain pessimism or at least a modicum of doubt as to whether the expected event will actually occur. As previously stressed, despite our theories being in the mainstay “provisional morals”, there is nothing at all pejorative about the word “theory” in academic circles. Quite the contrary, as laws are limited to the exact sciences, the most important body of knowledge the natural sciences can produce is precisely theoretical.

Evolution can never aspire to the realm of fact. As I also mentioned earlier, Science does not produce facts, it merely uses them to test its theories,

as it is the latter that allow us to predict the outcomes of phenomena. The greater a theory's power of prediction, the closer it has come to understanding the natural process to which it refers. The robustness of a theory is measured in how many facts it can foretell and explain.

Science can therefore never be a fact in itself. And there is not the slightest doubt that the Darwinian theory of evolution presents extraordinary capacity to explain and predict the processes of living nature in comparison with any other competitive theory. One need only remember that various evolutionary biologists predicted back in the 1950s and 1960s that the indiscriminate use of pesticides in agriculture and antibiotics in fighting infections in humans and animals would lead to the emergence of resistant strains of these compounds, by natural selection, in the reasonably near future.

The scientific study of human evolution must therefore be viewed within the context of the limitations of western science. Despite these – which will be gradually surmounted with time -, we can already make a series of deductions about specific moments in hominin evolution and describe the events laid down in the fossils with great processual elegance. Naturally, the further back in time we go, the more incomplete our understanding becomes, as the older the fossils, the rarer they are to come by.

That said, I am going to present some estimates and deductions about human evolution generated by palaeoanthropology back in the 1970s and which have been borne-out to the letter as new sites and fossil finds have come to light and been studied. I am taking the 1970s as a reference because it was only from then on that we had a sufficiently expressive volume of hominin fossils to work from, some dating back as far as four million years, a chronological milestone inconceivable back in the 1960s.

In the 1970s it became increasingly clear that, from the physical and behavioural characteristics of *Homo sapiens* and its closest surviving relatives, the great African apes^b in general and the chimpanzee in particular, our evolutionary saga unravelled more or less as follows (imagine this ancestor as an animal much like a modern chimpanzee): fixation of bipedalism; production of stone tools; expressive consumption of animal protein; the development of a large, complex brain; fixation of mental capacity for signification; creative and technological revolution; occupation of the entire planet.

Whenever you analyze a particular biological group from the present to the past you get the impression that there must have been some kind of blueprint being followed from the outset. If that had been the case, millions of evolutionary lines would not have come to a dead end in time. This impression is born of the fact that evolution is an historical process. Each evolutionary innovation to some degree funnels posterior innovations, but in no way predetermines the fixation of any particular next step over and above the various other possibilities.

This in no way signifies the fulfilment of some preordained plan or the existence of a grand design to be followed in pursuit of a preconceived end. Evolution has no blueprint^c.

As such, we can peremptorily state that we will never see an articulated arm like ours on an amoeba. The adaptive mechanisms that fixed along the evolutionary line of amoebas never came remotely close to anything resembling an articulated limb, hence the affirmation that there is nothing in the evolutionary history of the amoebic line that could make the slightest case for the sudden appearance of a functional arm, just like that, out of nothing.

As we all know, it takes millions of specialised cells for a limb to exist. Amoebas are unicellular organisms, which means that their evolutionary innovations will be restricted from the outset by this base condition. In short, it is impossible for a complex structure like an arm to appear on a unicellular organism, come what may.

Returning to the (post-facto) sequence I presented on human evolution, we can see that the liberation of the hands and the production of stone tools were not factors toward which selection was working when it opted for bipedalism among our ancestors. However, technological capacity would certainly not have been fixed by natural selection millions of years later had there not been, at that moment in time, a large bipedal ape roaming some African landscape with its hands already free to make and use tools. The production (and particularly the use) of stone tools would have aggregated little evolutionary value to a quadruped whose members were forever occupied with locomotion^d.

The First Bipedals

Bipedalism, bipedality or upright movement (Figure 2), has always taken up huge space in the palaeoanthropological literature in virtue of how rare this kind of locomotion is in the animal world. Of the primates, we alone became bipedal through sustained upright locomotion; one of the most important, if not the most important, exclusive markers of our evolutionary line.

Up until the mid-sixties, it was generally thought that all repertory that sets us apart from the great apes (i.e. orang-utan, gorilla and chimpanzee) emerged at roughly the same time, albeit incipiently, early on in our solo evolutionary career. In other words, my colleagues of just a few decades ago believed that bipedalism, technological capacity and large brain size – the most striking characteristics of *Homo sapiens* - were already there as a package in our earliest ancestors.

They could not have been more wrong! With the discovery of fossils of *Australopithecus afarensis* (the famous Lucy among them)(Figure 3) in Ethiopia and Tanzania in the mid-1970s, it became clear that bipedalism predated the appearance of large brains and technological capacity by millions

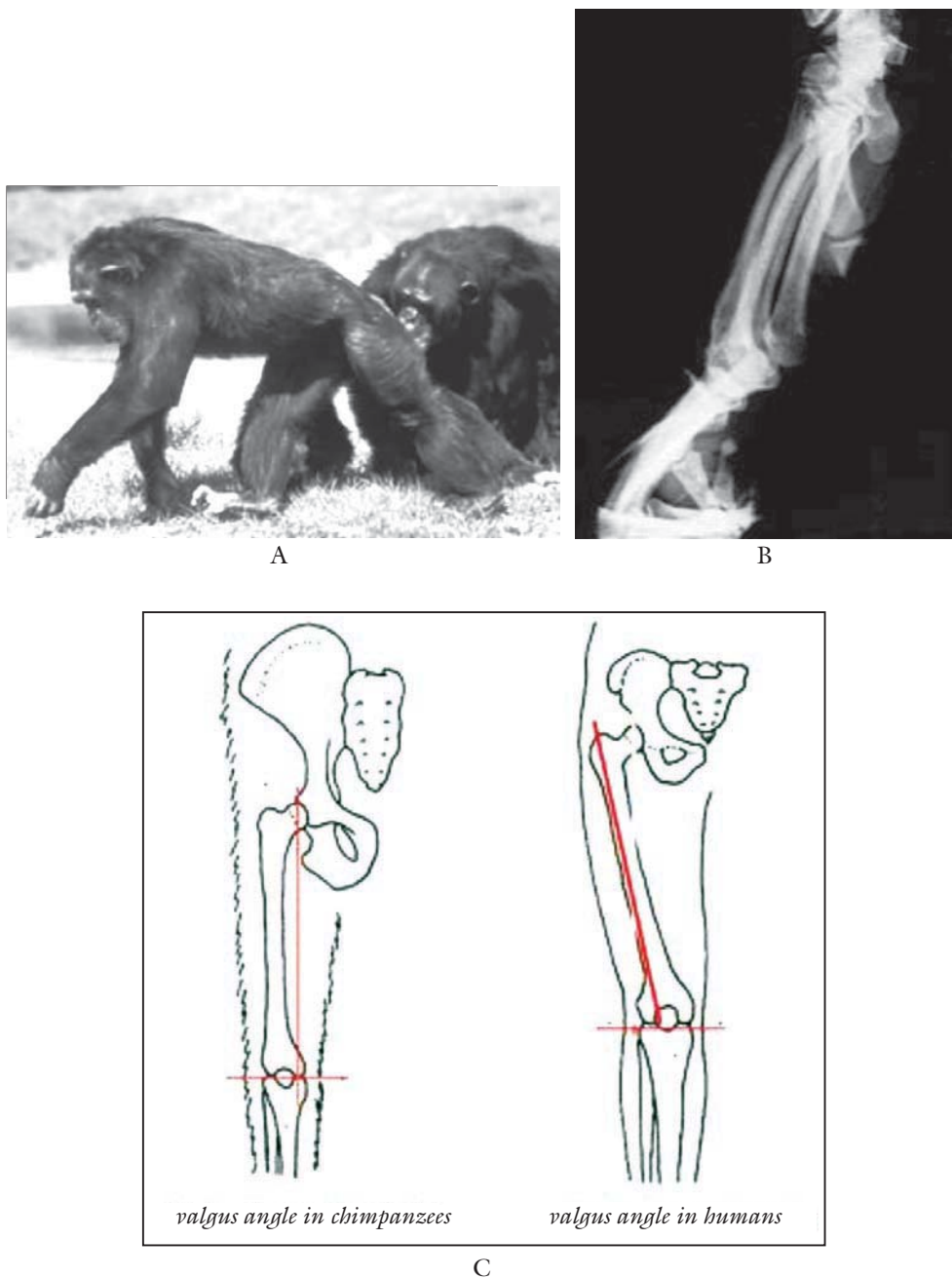


Figure 2 – (A) Knuckle-walking in chimpanzees. (B) X-ray image of a chimpanzee's arm while knuckle-walking. (C) Difference in the angle formed between the intersection of the femur and tibia at the knee in chimpanzees and humans (known as the valgus angle). The inclination in the human femur positions the feet at the body's centre of gravity, providing balance when upright and, consequently, allowing for sustained bipedality. [left: valgus angle in chimpanzees; right: valgus angle in humans]

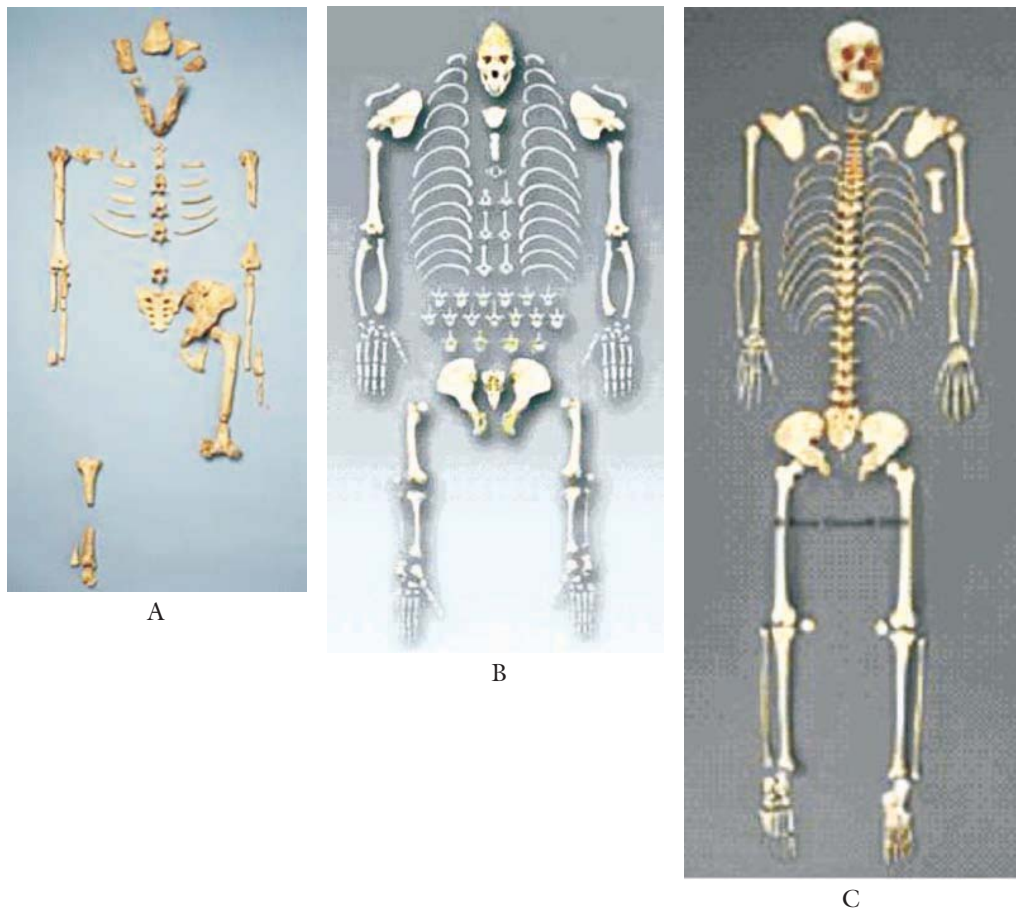
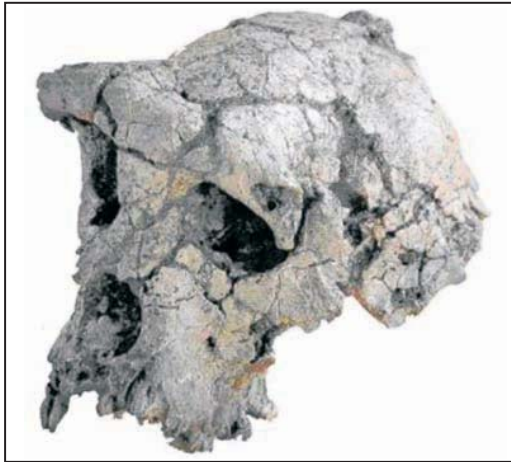
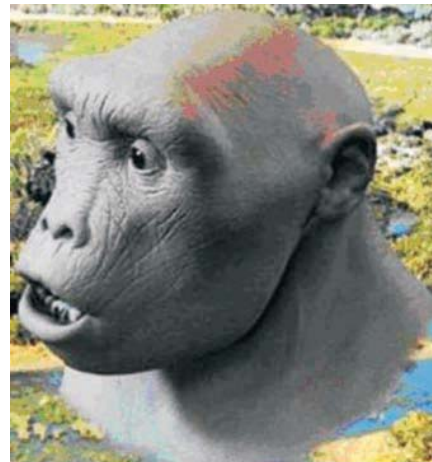


Figure 3 – (A) Partial skeleton of *Australopithecus afarensis*, found in 1974 in Hadar, Ethiopia. This specimen, known as Lucy, became extremely famous as what was then the oldest fossil evidence of hominin bipedalism (3.2 million before present [BP]). (B) Disjointed skeleton of a gorilla (*Gorilla gorilla*), an African great ape. Note the morphological similarity between its skeleton structure and that of the Australopithecine (Figure 3A) and modern humans (Figure 3C). (C) Disjointed skeleton of a modern human (*Homo sapiens*). Once again, note the morphological similarities with the anatomical structures of the Australopithecine (Figure 3A) and the great ape (Figure 3B).



A



B

Figure 4 – (A) Cranium of *Sahelanthropus tchadensis*, found at Toros-Melalla in the Sahel region of the southern Sahara in Chad. The specimen was nicknamed Toumaï (“Hope of life” in the local tongue) and is, its discoverers claim, the oldest hominin fossil ever found, thus pushing back the date for the emergence of bipedalism and, therefore, of our lineage to seven million years BP. (B) Reconstruction of the *Sahelanthropus tchadensis* cranium in vivo.

of years. Given the enormous time difference, it also became clear that tool production (and the competitive edge it gave) was not, as Darwin and many other important scientists would have had it, the selective driving force behind bipedalism (which, by extension, freed the hands for handicraft). We now know that the first bipeds, and thus the first hominins, emerged some seven million years ago, as represented by *Sahelanthropus tchadensis* (Figure 4), whose fossils were discovered at the beginning of the 21st Century in Chad.

From the information we had already accumulated during the 1970s, it was generally expected that the earliest hominins had to have been little more than upright chimps. In fact, besides *S. tchadensis*, the various other hominins discovered between 1990 and 2000 (*Orrorin tugenensis*, *Ardipithecus kadaba*, *Ardipithecus ramidus* and *Australopithecus anamensis*), all dated to between four and six million years ago, revealed themselves to have been highly primitive in terms of cranium and dentition. Such is the dental and cranial primitiveness in these species that various authors refuse to accept these fossils as pertaining to the hominin line (and thus as bipeds).

One example is *S. tchadensis*, who many believe to have been strikingly similar to the female gorilla. Further evidence is that the milk teeth of *A. ramidus*, from which the species was described, are very similar to those of a baby chimpanzee. The evidence becomes much more telling when we consider that too few bones were found from the pelvis and femur of these recently-described species for us to be able to affirm with any degree of certainty that they were in fact bipedal. One way or another, the expectation that the first pre-*A. afarensis* hominins were, bipedalism apart, all but indistinguishable cranially from the great apes was borne out to the letter by fresh fossil finds.

We now know that bipedalism was fixed in hominin evolution in two stages, which would make perfect sense in the light of evolutionary theory. The first hominins, from between seven and two and a half million years ago, though bipedal, preserved various arboreal characteristics, indicative of life both on the ground and in trees (Figure 5). Some believe that these hominins only took to the trees in order to flee or to sleep, but there is nothing to exclude the possibility that, like chimpanzees, they also collected fruits, seeds and shoots from those trees. A recent article based on 200 hours of observation of chimpanzees in the wild revealed that this great ape will often adopt bipedal posture while in the trees in order to reach the fruit on higher branches. Bipedalism may thus have derived primarily as postural rather than locomotive habit.

The dawn of bipedalism adapted exclusively for terrestrial locomotion occurred only 2.5 million years ago, roughly in coincidence with the emergence of the genus *Homo* in Africa. Only then did our bodies assume their current proportions in terms of trunk, legs and arms (Figure 6). Generally, the great apes have short legs and long arms, a physique suited to movement among tree branches. We, on the other hand, have relatively long

legs in comparison with arm length, a structure that equips us well for on-land movement but makes us lousy tree-climbers.

Table 1

Timeline of the main hominin species over the course of human evolution, with timeframes (in millions of years before the present) and location found.

Species	Chronology (millions of years BP)	Region found
Sahelanthropus tchadensis	7.0	Toros-Melalla, Chad
Orrorin tugenensis	6.0	Tugen Hills, Kenya
Ardipithecus kadabba	5.0	Middle Awash, Ethiopia
Ardipithecus ramidus	4.2	Middle Awash, Ethiopia
Australopithecus anamensis	between 4.2 and 3.9	Lake Turkana, Kenya
Australopithecus afarensis*	between 3.7 and 2.5	Hadar, Ethiopia; Laetoli, Tanzania
Australopithecus bahrelghazali	between 3.5 and 3.0	Chad
Kenyanthropus platyops	3.5	Kenya
Australopithecus africanus	3.0	Taung; Sterkfontein, South Africa
Australopithecus gahri	2.5	Ethiopia
Paranthropus robustus	between 2.0 and 1.0	Swartkrans; Kromdraai, South Africa
Paranthropus boisei	1.75	Olduvai Gorge, Tanzania; Lake Turkana, Kenya
Homo habilis	between 2.0 and 1.7	Olduvai Gorge, Tanzania; Lake Turkana, Kenya
Homo rudolfensis	2.3	Lake Turkana, Kenya; Malawi
Homo ergaster	between 2.0 and 1.4	Lake Turkana, Kenya; Dmanisi, Republic of Georgia
Homo erectus	between 1.8 and 0.03	Africa, Asia and Europe (?)
Homo heidelbergensis	between 0.8 and 0.2	Africa, Asia and Europe
Homo neanderthalensis	between 0.2 and 0.03	Europe and Middle East
Homo sapiens	0.2 – present	Originated in Africa, spread across the globe

* Also classified as *Praeanthropus africanus*

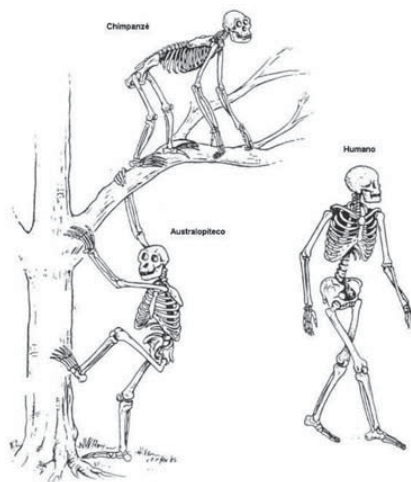


Figure 5 – (A) Comparison of the locomotive postures of the great apes (chimpanzee pictured here), Australopithecines and modern humans. Note that, unlike humans (structurally geared for bipedalism) and the apes (structurally arboreal knuckle-walkers), the Australopithecine skeleton is “intermediary”, with some structural characteristics associated with bipedality (valgus angle more similar to our own, for example), while retaining visibly arboreal features (arms proportionally much longer in relation to the legs, curved fingers and toes).

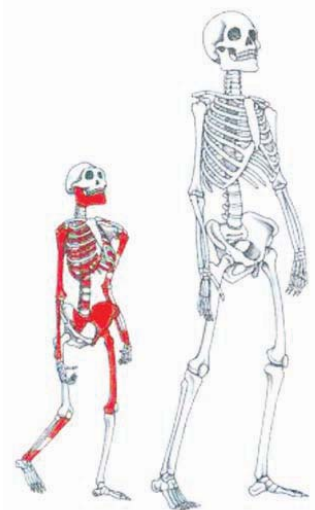


Figure 6 – Comparison of the “Lucy” skeleton (left) with that of a modern human female (right). The anatomical parts coloured in red are those found at the excavation site in 1974. Note that, compared with a modern woman, the australopithecine female was smaller, with a relatively small cranial capacity and proportionally longer arms.

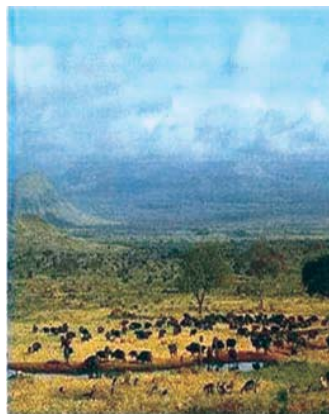
It is worth mentioning that precisely 2.5 million years ago Africa started to present a landscape configuration very similar to that of today, with large expanses of desert and savannah and few forests. It is possible that, in this new environmental context, the ability to scale a tree efficiently lost its adaptive value as forest turned to grassland and the tree's relevance as refuge and food source diminished (Figure 7).



(A)



(B)



(C)

Figure 7 – Three African landscapes. (A) Typical forest landscape, with densely-packed trees, heavy biomass and high humidity; (B) woodland, with sparse trees and bush, indicative of a warm climate with low rainfall; (C) savannah, typically dry, hot, semi-arid, largely exposed to the sun and with little exuberance in terms of vegetation. The environmental changes that began in Africa during the Miocene played an important role in the evolutionary history of primates and humans, as woodland gave way to grassland.

In short, the discovery of still partially-arboreal bipeds sits well with the Darwinian notion of the fixation of an upright posture from large knuckle-walking primates. Chimpanzees, gorillas and, to a certain extent, orang-utans

spend most of their time moving about with the vertebral column at an angle to the ground, with the legs slightly bent, the arms at full stretch and resting on the knuckles – hence the name knuckle-walking. While knuckle-walking is considered a form of quadrupedalism, the fact is that great ape locomotion no longer sees the trunk held parallel to the ground in the manner typical of quadrupeds (pronograde posture).

Our bipedalism must therefore have been the result of four significant evolutionary events in accumulative historical succession: orthograde posture (the freeing of the trunk), knuckle walking (the lengthening of the arms), arboreal bipedalism (the fixation of a low and wide pelvis) and, finally, exclusively terrestrial bipedalism (shorter arms, longer legs). This is a clear historical example of the evolutionary process and of how new adaptive characteristics can only be fixed if structures conducive to their appearance are already there, having themselves achieved fixation in early history by the same adaptive logic.

Tool-making and the Consumption of Animal Protein

To cut a long story as short as possible, there is no causal connection whatsoever between the production and use of stone tools and the fixation of bipedalism, as was commonly thought from Darwin to the 1970s. While bipedalism emerged some seven million years ago, the first tools would only appear nearly five million years later, as recently as 2.5 million BP. It may be true that the freeing of the hands, which must have allowed for the occurrence of some important activity in the evolution of our oldest ancestors, contributed in some form to the fixation of bipedalism, but certainly not the manufacture of stone tools^c.

Another dogma I will try to debunk here is that the hominins that crafted the first tools had superior cranial capacity to their predecessors, incapable of flaking. The bad news is that the first stone flakers (*Australopithecus garhi*) (Figure 8) had a cranial capacity very similar to that of their earliest bipedal ancestors: 450cm³. This, however, became perfectly acceptable once it was discovered that, if taught, the common chimpanzee was capable of grasping the usefulness of a stone flake in resolving problems of access to food, for example.

For motor reasons, the chimpanzee is unable to flake a stone in a controlled manner while using another rock for percussion, as the human can (see Figure 9). In other words, a brain little larger than a chimpanzee's (400cm³) is enough to understand the utility a stone flake can have in daily routine. The chimp has the necessary power of insight to grasp this, even if the anatomy of its hands prevents it from putting that notion to planned and controlled use.

Another myth long since dispelled, but with little divulgation in didactic books, due to staunch resistance to the idea, was that the first stone

toolmakers, whose toolbox basically consisted of choppers and chopping tools (Figure 10), already had a mental archetype of the tool they wanted to fashion when they set to work on those stone blocks, regardless of their original shapes.

Since the early 1980s it has become increasingly clearer to palaeoanthropologists that the first stone tool users really had no such mental blueprint from which to make their tools. The earliest toolbox contained a single instrument, and an informal one: flakes! What we once called choppers and chopping tools were nothing more than the remains of pebbles from which flakes had been removed by direct percussion and so used until their potential as raw material was exhausted. In this case, with so many flakes having been splintered from the surface in a largely chaotic manner, these pebbles or blocks became what are called “polyhedrons” or “spheroids”.

Under the old mindset, archaeologists never could explain the presence of these “polyhedrons” and “spheroids” at plio-pleistocene^f sites, as they had failed to grasp the function those “tools” had. Today we know that they were just pebbles and blocks of used up raw material. Occasionally the cores were used as ‘hammers’ to break open bones to get at the marrow, a function for which any rock at hand would have sufficed just as well.

No sooner had we understood that knapping had not, at least in the beginning, involved any preconceived mental template, and that even chimpanzees could be taught to knap stone, than we also realized that pre-Homo hominins, with cranial capacities much like the great apes, would also have been capable of knapping, given the right motor capacity.

Thus, when stone tools turned up alongside *Australopithecus ghari*, with its mere 450cm³-brain, in the late 1990s, we were not at all surprised, as it fit with the evolutionary perspective created by the observations above. Nor did it surprise us to find in that same geological layer, mixed in with the stone flakes, broken antelope bones bearing cut marks.

While we still do not have a universally acceptable model to explain the fixation of bipedalism around seven million years ago, what is clear to we palaeoanthropologists is that the selective pressure that led to the fixation of the ability to make and use stone tools was access to animal protein in expressive amounts. As already mentioned, it was at this very moment, roughly 2.5 million years ago, that the savannization process began to take place in Africa, giving it the countenance we recognise today.

As is well known, the African savannah is poor in vegetal fare^g, with the wildlife, particularly grazers like the gazelle, zebra and antelope, providing the main source of protein and energy-rich food on these landscapes. For the hominins, recently driven onto the savannahs by forest competitors, the main problem would have been how to go about actively and deliberately slaughtering this kind of prey, deprived as we were of large canines or claws, or any of the other natural endowments required for killing large mammals.

Another problem was how to deal with the competitors for these carcasses, chiefly the large felines, hyenas, jackals and vultures so abundant around the watering holes and rivers and always on the look out for a free meal.

The advent of knapping and the systematic production of flakes with a cutting-edge solved both problems and won our ancestors a rich and relatively technologically undemanding niche in the savannah, namely the scavenging of carcasses left behind by the large felines. On the one hand, this spared the first tool-makers the need to come up with formal tools to slay large prey, while, on the other, the flakes enabled them to swiftly skin and strip the left-over meat and tendons before scurrying back to safer ground to consume the food snatched from the “eye of the storm”.

This was undoubtedly a collective task, especially as the hyenas and vultures would have also been vying for the freshest carcasses, so a lone scavenger would hardly have managed to skin the animal, cut away the meat and tendon, perhaps even entire bones for the marrow, while fending off his fiercest competitors. Chimpanzees, on the rare occasions that they hunt small prey, such as colobus monkeys or lizards, are also capable of working in bands. So, once again, we need not factor in extravagant intellectual abilities in order to imagine our ape-like ancestors executing such a task.

The ability to knap flakes out of stone had an enormous impact on human evolution. And this toolkit remained practically unchanged for around a million years, until finally replaced by the first few formal tools at around 1.6 million BP (Figure 11). It is a perfect example of how a small evolutionary innovation can unlock previously inaccessible ecological niches allowing a hitherto geographically limited group to achieve considerable adaptive spread.

In this case it is hard to judge which came first, the ability to make stone tools or the consumption of animal protein. It is possible that they emerged synergistically, as tends to happen with adaptive processes. What is clear, however, is that the fixation of knapping as a daily activity certainly occurred as a way of facilitating access to animal protein in a highly competitive environment lacking in vegetal resources of any real nutritional quality.

I fear that the way I have constructed my arguments here might lead the reader to precisely the line of thought I wanted to debunk: that there is an end, a blueprint, a target to be reached by evolution. I want to continue with my current theme in order to demonstrate how the synergy of the two phenomena dealt with above can be readily explained in a totally non-finalist, non-teleological way, as we say in academia.

Imagine a group of bipeds living in increasingly receding forests surrounded by expanding savannah. Obviously, as the forest dwindles, so too does the fruit supply, creating stiffer competition between hominis for what is their main source of calories. As in all populations, where physical and behavioural characteristics vary greatly, some bolder individuals may have



Figure 8 – Cranium of *Australopithecus ghari*, a fossil unearthed in the Awash River valley, Ethiopia, in 1996. These fossil fragments were found at the Bouri site, not far from where another Australopithecine, *Australopithecus afarensis*, was found. The age of the fossil has been estimated at 2.5 million years. In 1997, the same team found cranial and post-cranial bone fragments just 300 metres from where the first ghari was encountered. Though this newer specimen was classified as belonging to the same species, analysis of the fragments indicated great variability among the Bouri hominids. *A. ghari* (ghari means “surprise” in the local tongue) had small cranial capacity, around 450 cc, and a far more protrusive face (prognathism) than other Australopithecines, as well as larger teeth. *Australopithecus ghari* was the first hominid to knap and use flakes as cutters to remove meat, tendon and marrow from large carcasses.

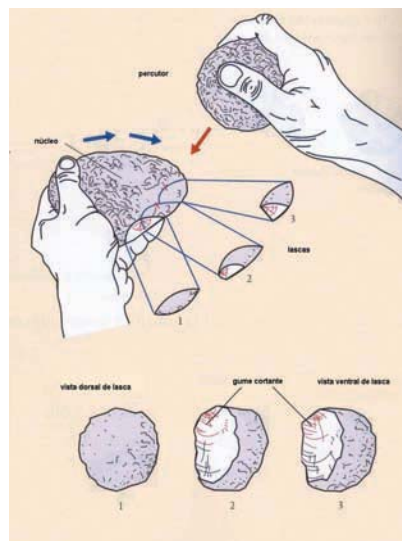


Figure 9 – Flakes were the first stone tools produced by controlled deliberate, aimed blows. Many myths have developed around the analysis of these tools, some of them concerning which hominin might have been responsible for their invention. Today, *Australopithecus ghari* is generally accepted as the most likely inventor of this technology, despite being endowed with a brain only slightly bigger than that of a chimpanzee. The differential that likely enabled *A. ghari* to innovate in this way was its bone structure, especially the anatomy of the hands, which would have allowed it to hold a stone firmly in the left hand while levelling precise blows against another stone held in the right.



Figure 10 – The Oldowan industry, named after Olduvai Gorge in East Africa, where it was first found. Represented here by two pebbles with various flakes removed.

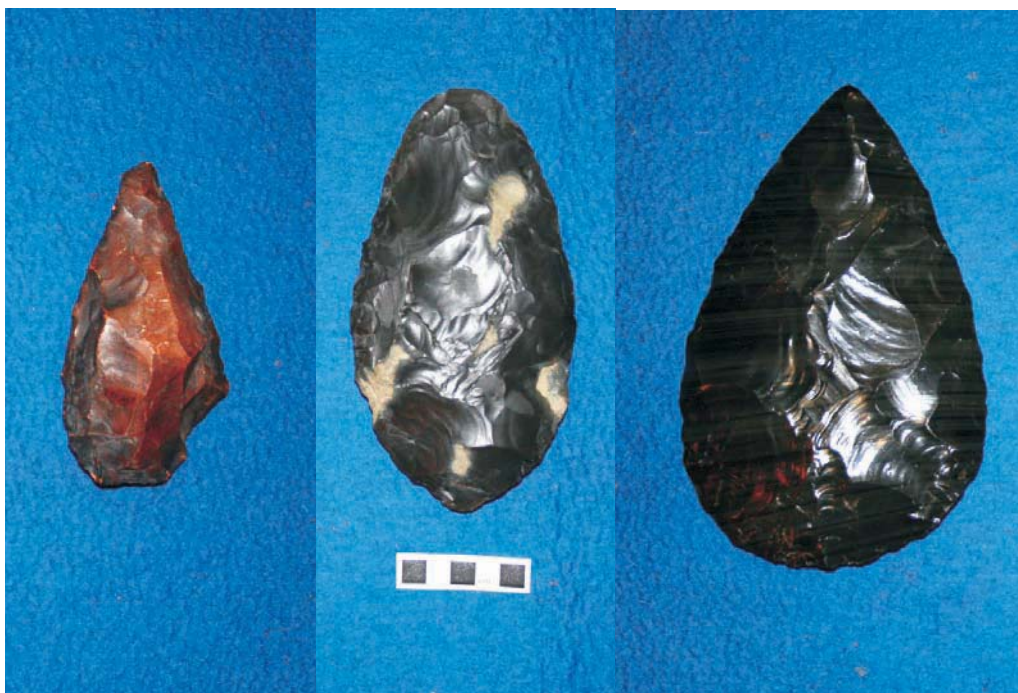


Figure 11 – The Acheulian industry, so named for having been first described at the Saint Acheul site in France, though also found in Africa, Europe and Asia. Note that two technological innovations on the Oldowan industry (flakes) are discernible here: the emergence of an archetype, that is, the reproduction of a pre-established mental template; and the emergence of specialized tools. The photo shows hand-axes displaying the marks of a much more refined flaking.

started making brief forays into the grasslands in search of new food resources. If these variants (or mutants, as many like to call them) included individuals with more refined dexterity enabling them to knap flakes from stones, they would certainly have enjoyed an edge in terms of access to the choicest cuts the savannah had to offer: carrion.

Given their access to a new food source rich in nutrients, these individuals would certainly have outbred their competitors, swelling their populations and passing their characteristics down to succeeding generations,

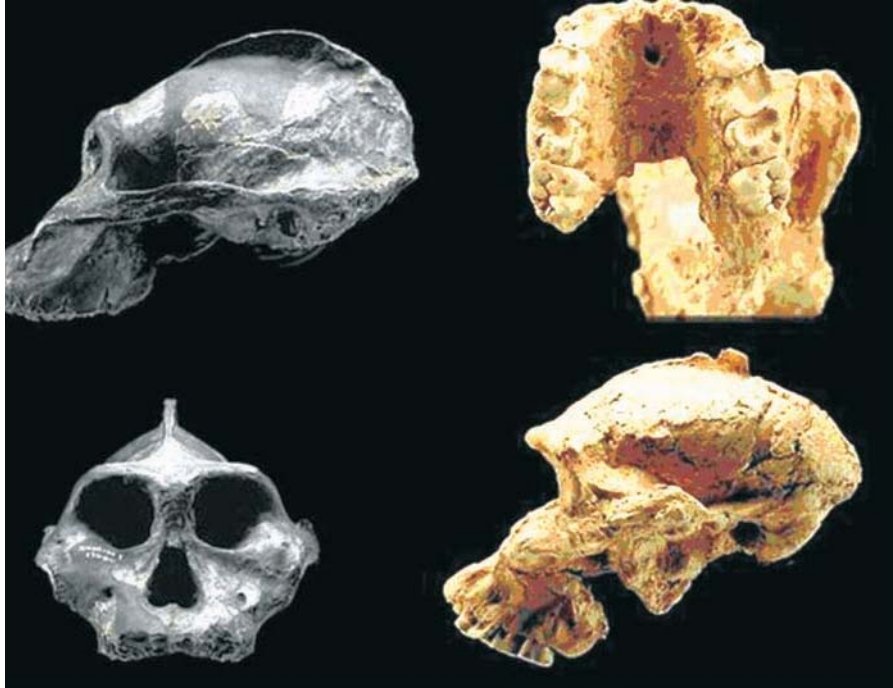


Figure 12 – The megadonts are here represented by two species of the genus *Paranthropus*, *aethiopicus* and *robustus* (there is also a third member of the genus, *Paranthropus boisei*). The genus name translates as “parallel to man”, an indication of the status attributed to them when first described by Robert Broom. The *Paranthropines* were very similar to the *Australopithecines* except for their morphological adaption for heavy chewing. These adaptations are very evident from the shape, size and thickness of the enamel on their teeth (efficient for masticating large volumes of tough vegetation) and from their cranial structure, such as the sagittal crest, supraorbital torus and lateral zygomatic expansion, which would have enabled the fixation of powerful masticating muscles. The *Paranthropines* lived alongside the *Australopithecines* on the African plains between 2.7 and 1.4 million BP, one of the periods of greatest diversity in the history of hominin evolution.

perhaps fine-tuned with time. When a physical or behavioural characteristic achieves widespread or total frequency in a given population we say that it has been fixed by natural selection.

Despite the simplicity of my example, which certainly fails to reflect all of the nuances of the real context, I hope that, precisely because of that simplicity, the reader may be convinced that a development that would appear to demand teleology or a pre-defined plan can actually be explained by the reverse: chance. Nevertheless, some may insist that it is just too fortuitous that a variant hominin with unusual manual dexterity happened to coincide with the expansion of the savannahs. Evolutionary theory has but one explanation for these grand coincidences: time! A lot of time! It must be remembered that evolutionary processes unfold over thousands or millions of years, giving the “right” accident a better chance of happening, so to speak.

Besides scavenging, could there have been other viable ecological niches on the savannahs 2.5 million years ago that might have been explored by those first bipeds pushed onto the plains by mounting competition? The answer is a resounding yes! Curiously, among the fossils dating to 2.5 million BP, there are some that display enormous teeth (megadonty), especially the premolars and molars, and skulls reinforced with a range of secondary structures, such as a bone bar across the brow (torus) and a sagittal crest (Figure 12), adapted to sustain powerful musculature for chewing.

A similar phenomenon can be seen in gorillas, which mainly feed off shoots and leaves. Kilos and kilos of shoots and leaves, that is, given their poor nutritional value. In general, the adaptations specific to animals that live off vegetal foodstuffs low in nutrients are enlarged back teeth, which expands the chewing area, and a digestive tract that ferments a large alimentary ball. Gorillas are often obliged to forage for hours on end to compensate for the low nutritional value of what they eat.

So when these hyper-robust hominins were found in the palaeontological register, there was no difficulty in interpreting them adaptively: they represented a hominin line that had evolved in parallel with their scavenging cousins and which survived on grassland fare with little nutritional value, pulverized, ingested and digested in large volumes for long periods of the day. This is what we evolutionists term niche differentiation. It is not unusual to see two similar animal groups adapting differently to the same landscape by exploring different ecological niches, therefore avoiding direct competition for the same resources.

Evidence of the existence of two hominin lines on the African savannah at 2.5 million BP, one exploring resources with a high nutritional value, though requiring technological innovation, and the other exploring more marginal resources, came as no great surprise, especially as niche differentiation is a more or less common phenomena in the evolution of living beings and there was no reason to think it might not have happened among hominins.

However, the bottom line that must be remembered is that the vegetarian line described above became extinct around a million years ago, while the carnivorous line (or omnivorous, as they would certainly have eaten vegetal foods too, when available) lives on today. When the cranial capacity of the megadonts from 2.5 million years ago is compared with that of the last descendants, dated to around a million BP, no significant neurocranial expansion can be noted, unlike in the genus *Homo*.

Once again, human evolution presents us with a fact that can be easily explained by what we already know about animal physiology from an ecological and adaptive perspective. The brain is a very expensive organ to maintain in terms of calories. 20% to 30% of the energy we consume goes into keeping our large brains running. It is impossible for a strict vegetarian living off a nutritionally poor diet to maintain a large brain, especially when much of the energy it consumes goes into powering its huge digestive system.

Hence a concept many people unfamiliar with Darwinian theory find hard to grasp: natural selection does not always have an “adaptive solution” up its sleeve, much less a “perfect adaptive solution”. The Paranthropines are an excellent illustration of how millions of lines of living beings have become



Figure 13 – Side view of the skull of a male gorilla. Note the similarity with the anatomical features described in the Paranthropines, such as the sagittal crest, large molars and ample space between the zygomatic arch and the temporal bone, all traits geared towards heavy chewing. The similarities between these gorilla characteristics and those identified in Paranthropus fossils were a great help in interpreting the feeding habits of megadontic hominins.

extinct. Most of the time the solution fixed is not ideal, but merely the best available stopgap. There is no physiological mechanism in nature capable of engineering an animal at once big-bodied and big-brained that lives exclusively off plant food of low nutritional value. The teleological idea of a preconceived plan receives its death-blow right here.

As mentioned earlier, the gorilla (Figure 13) and its eating habits helped a lot in interpreting the megadontic fossils. Once again, evolutionary theory was essential in understanding the phenomenon: it is not unusual in nature for two very different animals, perhaps even from very different lines, to have their adaptive problems “solved” by the fixation of very similar anatomical features. This mechanism, known as parallel or convergent evolution, is clear proof that if there were a blueprint and architect behind biological evolution, both could be described as mediocre, or at least as less than creative, as in the evolution of living beings this single “strategy” has been used and abused to “solve” various similar, though independent problems.

If we go back to our original story, we have to admit that, in parallel with variants endowed with better manual dexterity, variants with above-average masticatory capacity must also have existed in the African forests during their gradual conversion to savannah. So just as natural selection favoured the fixation of the capacity for knapping and social organization among those who already demonstrated greater manual motor skills, thus giving rise to a line of scavengers, it also fixed and enhanced megadonty, producing a strictly vegetarian line.

Big and Complex Brains

It is very difficult to tell exactly when the hominin brain started to enlarge. It all depends on whether you use the criterion of cranial capacity or the coefficient of encephalization (brain-to-body ratio). Obviously there will be a proportion between the body size and brain size; an elephant, for example, has much greater encephalic mass than we.

The majority of the brain is devoted to maintaining the functioning of the basic physiological processes of the metabolism. So when body-size increases, brain-size grows accordingly, even without there being an environmental demand for more cognitive power or intelligence.

One way or the other, the first members of our genus (*Homo ergaster/erectus*^{d)} (Figure 14) seem to have also been the first to display cranial capacity significantly larger than our predecessors, the Australopithecinesⁱ (Table 2). With an average cranial capacity of 750 cm³, these truly broke the 550cm³ barrier, a ceiling much like that of the great apes.

That said, cranial capacity varies widely among the earliest *Homo* specimens. For example, in the early years of the decade 2000, three specimens of this group were found in the Republic of Georgia in the Caucasus, with cranial capacities varying from 600 to 780 cm³, all adults.

Furthermore, the emergence of the genus *Homo* may have implied an increase in hominin stature, enlarging body mass. When the brain volume is divided by the body mass, the ratio of encephalization for early *Homo* does not put them far beyond the Australopithecines.

What does seem to mark the emergence of the genus *Homo* was the fixation of exclusively terrestrial bipedalism as opposed to the semi-arboreal tendencies of the Australopithecines. The dawn of *Homo* does not seem to



Figure 14 – The complicated relationship between *Homo ergaster* and *Homo erectus* is well exemplified in the fossil above, KMN-ER-15000, nicknamed Turkana Boy, found in 1984 on the banks of the Nariokotome River, near the western shore of Lake Turkana, Kenya. With an estimated age of 1.6 million years, this specimen has been classified as both *Homo ergaster* and *Homo erectus*. The taxonomical confusion surrounding these two species stems from the many similarities and few differences between their skeletons, leading to a host of paleoanthropological interpretations. At around 1.6 million BP, both were using Acheulian tools, and they were the first hominins to make it out of Africa and colonize Eurasia (approx. 1.75 million BP).

come packed with grand cognitive innovations. The toolkit is still restricted to cutting-edge flakes. Subsistence is still carrion-based. But even with these restrictions, what the Georgian specimens do tell us is that the first representatives of our genus were the pioneering migrants to leave Africa, and not long after they originated there 1.8 million years ago (the fossils from Dmanisi in the Georgian Republic are reliably dated to 1.75 million BP).

Table 2

Timeline of the main hominin species over the course of human evolution, with timeframes (in millions of years before the present) and their average cranial capacities.

Species	Chronology (millions of years BP)	Cranial Capacity in cm ³
<i>Sahelanthropus tchadensis</i>	7.0	Between 320 and 350
<i>Orrorin tugenensis</i>	6.0	?
<i>Ardipithecus kadabba</i>	5.0	?
<i>Australopithecus anamensis</i>	between 4.2 and 3.9	?
<i>Australopithecus afarensis</i> *	between 3.7 and 2.5	around 400
<i>Australopithecus bahrelg-hazali</i>	between 3.5 and 3.0	?
<i>Kenyanthropus platyops</i>	3.5	?
<i>Australopithecus africanus</i>	3.0	around 440
<i>Australopithecus gahri</i>	2.5	around 450
<i>Paranthropus aethiopicus</i>	2.7	around 410
<i>Paranthropus robustus</i>	between 2 and 1	around 530
<i>Paranthropus boisei</i>	1.75	around 500
<i>Homo habilis</i>	between 2.0 and 1.7	around 680
<i>Homo rudolfensis</i>	2.3	around 775
<i>Homo ergaster</i>	between 2.0 and 1.4	around 850
<i>Homo erectus</i>	between 1.8 and 0.03	between 850 and
<i>Homo heidelbergensis</i>	between 0.8 and 0.2	around 1000
<i>Homo neanderthalensis</i>	between 0.2 and 0.03	around 1450
<i>Homo sapiens</i>	0.2 – present	around 1350

* Also classified as *Praeanthropus africanus*

This modest brain growth at the beginning of our genus makes total sense from a contextual evolutionary perspective. As I have said, it doesn't take a brain much larger than that of a chimpanzee to make flakes sharp enough to

slice meat and tendon from the bones of fresh carcasses. It is therefore possible that the increase in cranial capacity was a consequence of larger body mass.

Research done with South-American monkeys has shown that those with the highest encephalization coefficient are not the ones most reliant on keen cognition to form and store mental maps of sources of nutrient-rich foods throughout the landscape, but those that live in larger troupes. The larger the group, the more social interaction that needs to be managed. It may be that, at that particular moment in hominin evolution, the fixation of a bolder social intelligence was more advantageous than an increase in natural history/technological intelligences.

As mentioned before, scavenging for fresh carrion certainly required cooperation among many individuals, and the preservation of this cooperation would have been based on reciprocity, just as among the great apes today, whenever they form some kind of alliance. In this case, the capacity to store precise and selective memory about the behaviour of partners in prior situations of cooperation would be extremely adaptive in terms of, for example, excluding those who had made off with all the meat while the rest of the band risked their lives fighting off hyenas and vultures. This is what we call Machiavellian or social intelligence.

As for increased body size, the phenomenon is common in animal evolution as a response to predators. Here too we can draw up a hypothetical model for how the increase in stature occurred in early *Homo* without recourse to teleologies. For sure, as in any natural population, there must have been individuals among the hominins that ventured out onto the savannahs that had very distinct genetically-determined statures. The larger or taller an animal is, the more easily it can scare away potential predators. It is possible that larger individuals began to survive attacks by hyenas and felines with more frequency than their shorter fellows and, consequently, passed on more of their genes to future generations. Depending on the differential in survival rates among larger and smaller individuals, an increase in average stature could have been swiftly fixed by natural selection.

Going back to locomotion, the fixation of strictly terrestrial bipedalism at this point in time also makes perfect sense. As I have underscored various times, the daily routine of early *Homo* was undeniably linked with the savannah; an open landscape with sparse trees. On such a terrain, tree-climbing as an escape strategy would no longer have provided quite the survival advantage it had for *Homo*'s forest-dwelling predecessors.

Finding fresh carcasses, however, would have involved long walks through the grasslands in search of opportunities. In this context, the fixation of shorter arms and longer legs would certainly have been favoured by natural selection, if these variants already existed, however modestly, among the populations braving Africa's recently generalized open plains for the first time in search of food resources.

Meaning/Creative Revolution/Cosmopolitanism

No hominin before *Homo sapiens* used bone, teeth or horns as raw material for the production of handicrafts. Nor did they imprint any personal or group style on the stone tools they produced, regardless of their technical prowess. The most sophisticated toolkit of our most brilliant predecessors, the Neanderthals, never made it imprint any personal or group style on the stone tools they produced (Figure 15). They didn't even bury their dead in a ritual way. No adornments, painted cave walls, or any other clearly artistic or aesthetic manifestations were found anywhere prior to the appearance of modern man.

The picture presented above could not be more different when compared with our current repertoire of behaviours and attitudes. Briefly put, one could say that everything in our lives, our behaviour, our routine is unquestionably marked by the attribution of meaning, of symbolic and subjective values, to everything we formulate or with which we interact. Otherwise stated, meaning permeates every dimension of our lives. From the moment we are born to the moment we die we are permanently tangled in a web of meaning. Indeed, we now know that the attribution of meaning is the only characteristic that qualitatively distinguishes humanity from the rest of the animal kingdom.

Many of our other “noble” characteristics, such as complex practical problem-solving, the production and use of tools and dependence upon acquired behaviours, we now know to exist to varying degrees in other animals too, especially when we consider the primates in general and the great apes in particular. We can conclude, therefore, that the presence of what we can call humanity is something relatively new to the planet.

Few people know that our unlimited creativity, from which we distil our technologies and all abstract thought, including mathematics, for example, emerged in hominids only as recently as -and indeed because of - our capacity to generate and share meaning. In other words, the same module^j of intelligence that generated our capacity for meaning also engendered the boundless creativity that pervades all walks of human life. That is why those “noble characteristics” would balloon exponentially in degree in man when compared with the animal kingdom as a whole, including the great apes.

Some specialists believe that symbolic meaning and our unlimited creativity derived from the fixation of a new module in our minds that integrated all the other modules previously fixed by natural selection, such as natural history intelligence, social intelligence and technical intelligence^k. Others believe that the boundaries between the specialized modules simply dissolved, allowing for greater flux between them. This fluidity, they argue, as an emerging property in complex systems, caused symbolic meaning and creativity to flourish.

Our most complex symbolic system is articulated speech, the capacity to share a language with the rest of our group through which things, feelings, times, actions and intentions can be expressed in a fluid, precise and extremely synthetic manner. However long we may have possessed all the elements needed to produce sounds on the same scale as we do today, articulated speech only truly arrived with the fixation of the capacity for signification in the human mind by natural selection - in other words, only once we had learned to associate sounds with real and abstract entities intersubjectively.

For me, as for many colleagues, the capacity for precise social communication was probably the adaptive reason that led selection to fix the mental module for symbolic meaning, despite the irrational and far from adaptive behaviours it produced as collateral effects (one thinks of the sacred cow in India, for example). It was from that point on that we were to become the existential, angst-ridden creatures we are today.

In other words, while extremely efficient problem-solving hominins existed long before we came along (the Neanderthals, for instance), their operational capacity never touched upon synthetic meaning: they had content, but no meaning. It is practically impossible for us to imagine how that could have worked, steeped as we are from head to toe in symbolic meaning and abstract values. The closest example would be Dr. Spock from *Star Trek*. No Neanderthal ever looked up at the stars and asked “Whence I came? Why am I here? Whither I go?”

The worst news, however, is yet to come. We modern humans had been just the same as they for tens of thousands of years. *Homo sapiens* emerged in Africa (for a change) some 200 thousand years ago (Figure 16). From the dawn of our history up until just 45 thousand years ago we did not have the symbolic module either. When we examine the behaviour of the first humans, we find that it is indistinguishable from that of the Neanderthals, for example. Between 200 and 45 thousand years ago, we did not bury our dead in a ritual manner either, nor did we use bone, tooth or horn as raw material, nor had we produced one single material aesthetic manifestation, and our toolkit was no better stocked than that of our immediate predecessors.

The symbolic revolution, or the creative revolution of the Upper Paleolithic, as it is known, happened only 45 thousand years ago. Hence it is often said that modern man is the product of two distinct evolutionary events. First, the emergence of anatomically (read: skeletally) modern humans at round 200 thousand BP, followed by the emergence of behaviourally modern humans at 45 thousand. And it was only after this creative revolution of the Upper Paleolithic that *Homo sapiens* poured out of Africa to replace the various existing hominids the world over, including the celebrated Neanderthals of Europe and the Middle East, who took their final bow at around 29 thousand years ago.

The modern mind that flowered 45 thousand years ago^m engendered creativity and symbolism in all dimensions of life: the stone toolkit, previously

composed of twenty specialized instruments almost quadrupled to roughly 75 implements (Figure 17); the forms of these instruments, though crafted to meet specific needs, also began to display personal and group styles, thus expressing individual and collective identities (ethnicity); bone, horn and teeth became standard, everyday raw materials (Figure 18); adornments became articles of popular use; the dead were now buried with elaborate ritual (Figure 19); bone tools were richly decorated (Figure 20) and, last but certainly not least, sculptures and wall paintings began to abound (Figure 21).

Now endowed with a mind more complex and powerful than anything that had gone before it in hominid evolution, we were able to occupy regions hitherto inaccessible, such as the high northern latitudes, where survival in the intense cold demanded unprecedentedly intricate technologies of adaptation and precise forms of communication.

The specific selective driving force behind the fixation of symbolic thought has not yet been determined with any level of accuracy. One candidate, as I have already mentioned, is that it gave rise to more precise communication among our ancestors. However, many other possibilities have been raised and investigated. Whatever the explanation, this last great evolutionary event in the hominin line took place without effecting any skeletal change. It worked its magic on the brain alone, the raw material of our minds. For this very reason we will never understand it fully, as the fossils could never give what that would take.

The result remains, however, that we are the only creature on earth capable of symbolic thought. This is, in fact, our only “singularity”, our only feature not shared with the rest of the animal kingdom. And this is no trivial singularity. For the first time in evolutionary history, natural selection fixed a mechanism capable of producing mal-adaptive behaviours, as mentioned before.

Natural selection fixed in us a mental entity that lies, at least partially, outside its own jurisdiction. An entity with a life of its own, largely generated by arbitrary, non-adaptive criteria grounded in abstract and non-rational principles. For some reason, this entity must have given us some immense adaptive advantage in the highly competitive world of the Upper Pleistocene, at least enough to neutralise our various irrational impulses driven by abstract values. Perhaps what we lost in adaptation, we gained in adaptability.

Once again, the concept of biological evolution as a historical process can help us resolve the apparent paradox. The fixation of symbolic signification in man rested upon extremely specific foundations. In the evolutionary past natural selection had already endowed our immediate ancestors with physical and mental characteristics that were highly propitious to cognitive “turbo-charging”: upper limbs entirely free to implement the technological innovations conceived of in the mind; hands gifted with near-unlimited capacity for prehensile precision; a diet rich in protein and energy; high



Figure 15 – Tools from the Mousterian Industry. Compared with earlier industries, the technology widely used by the Neanderthals and some of their precursors presented a great deal of variety in terms of shape and specific function. This variability was possible thanks to certain technological advances, particularly that of knapping from a prepared core, which allowed the toolmaker more control over the size and shape of the flakes, which could be produced in roughly the format of the desired tool, requiring only marginal retouch.

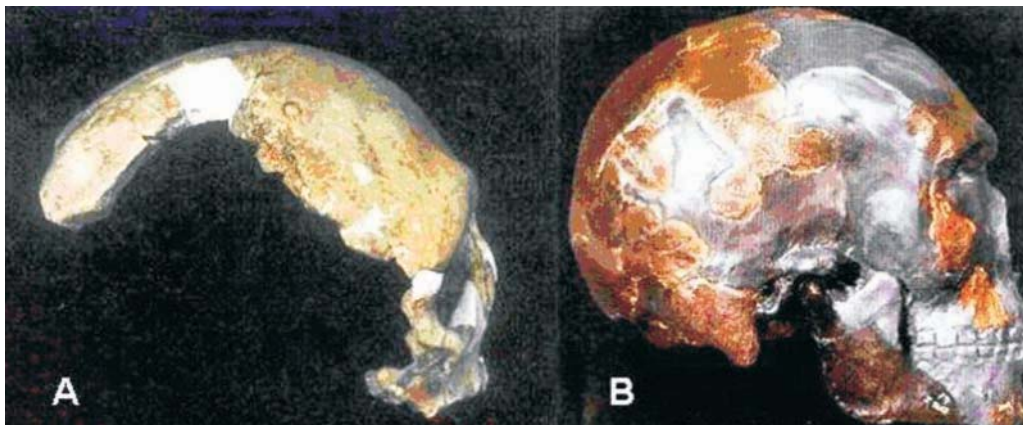


Figure 16 – (A) Skullcap from the Florisbad site in South Africa. The fossil presents series of features common to both *Homo sapiens* and *Homo hiedelbergensis* and is dated to somewhere between 200 and 300 thousand years ago. (B) The fossil known as Omo-Kibish 1, found in Ethiopia in 1963 and recently dated to 190 thousand BP. The cranium presents all of the morphological features common to modern humans and is accepted in the paleoanthropological community to be the oldest known fossil of our species.



Figure 17 – Upper Paleolithic stone tools. With the creative revolution, mastery of blade flaking techniques and the use of bone, horn and teeth in the manufacture of tools, the Homo sapiens of the Upper Paleolithic experienced a technological boom like never before seen in hominin history. This expertise gave mankind access to environments that would have been inaccessible and utterly hostile to its ancestors, making it possible for first time in human evolution for a hominin species to become totally cosmopolitan, as we are today.

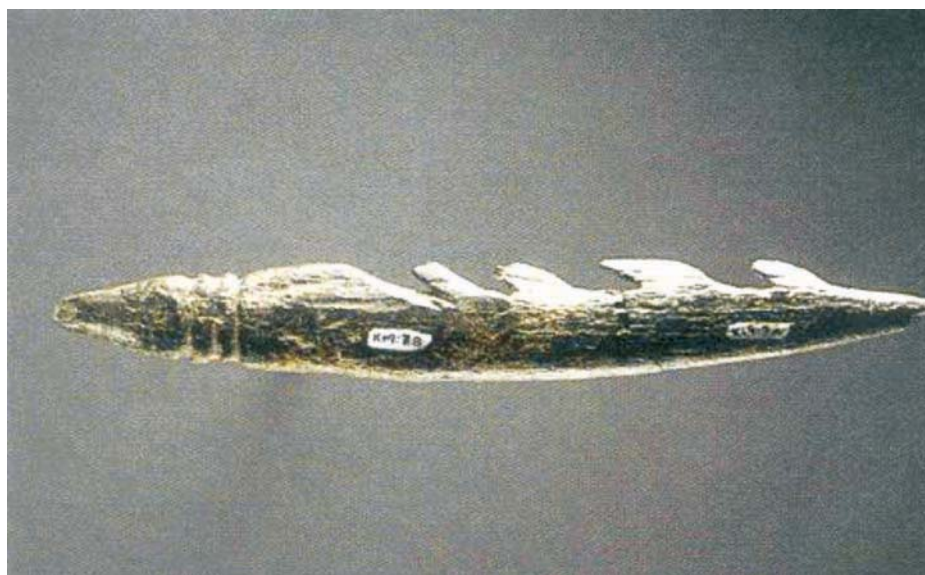


Figure 18 – Harpoon head in worked bone found in Katanda, present-day Republic of Congo, Africa, dated to roughly 70 thousand years ago.



Figure 19 – Heavily adorned human remains found in a grave in Sungir, Russia. This type of burial is a milestone in human evolution, as it shows when and how our ancestors began to ask questions, such as who we are, what we are doing here and what happens to our existence after death. This type of questioning only began after the fixation of the capacity for symbolic thought in the mind of Homo sapiens.

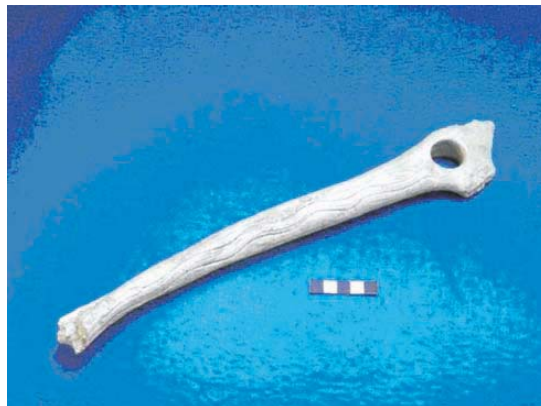


Figure 20 – Command stick. Another consequence of human cultural development after the Upper Paleolithic revolution was the dawn of culture properly speaking, as we know it today. The picture shows a carved animal bone which some archaeologists believe to be a command stick or some such emblem of power used by group leaders in the Upper Paleolithic.

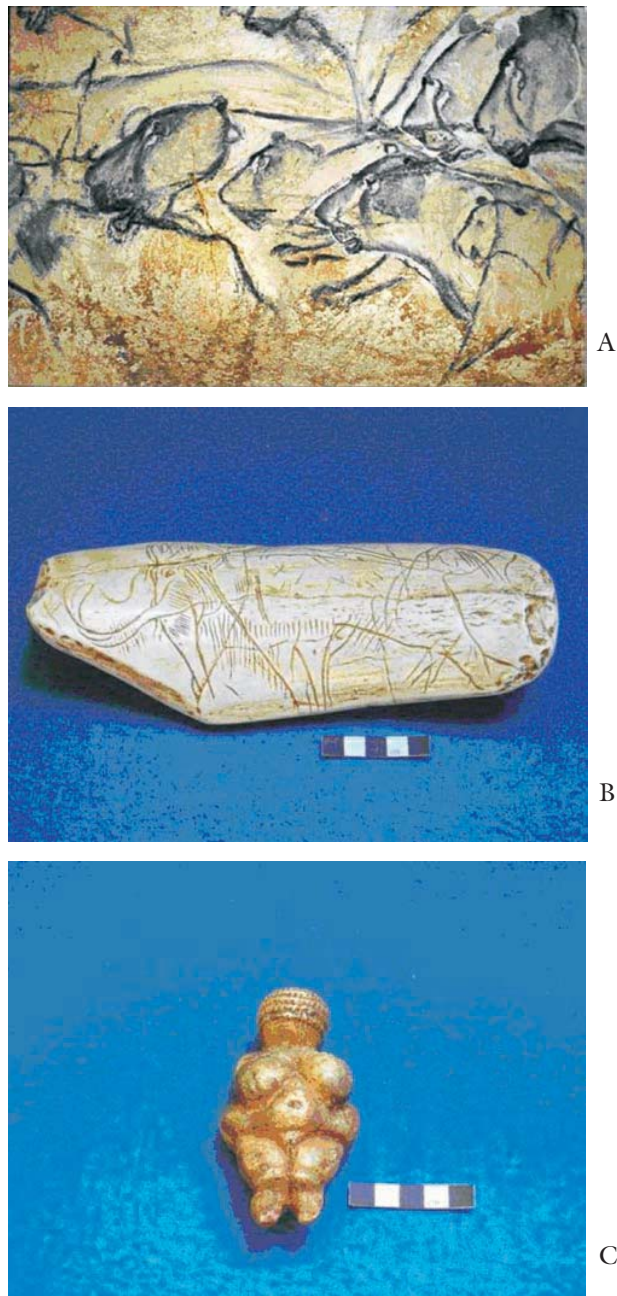


Figure 21 – The first examples of artistic expression also depended upon the Upper Paleolithic revolution. Images and objects portraying daily activities, representing divinities or indicating social status only began to emerge after 45 thousand BP. The Figures above show three examples of Upper Paleolithic art: (A) cave paintings at Chauvet, dated to 36 thousand years ago; (B) drawing of a mammoth carved from a mammoth tusk, from Le Magdeleine (Dordogne); (C) Venus of Willendorff, Austria, dated to somewhere between 20 and 25 thousand years ago.

technological capacity for complex problem-solving; large, close-knit groups with gender-specific division of labour (hunting = men; gathering = women and children); and precise mapping of the natural resources available in the environs.

Given the arbitrary nature of symbols, had there been nothing there to turbo-charge, the fixation of symbolic signification would certainly have served only and hopelessly to engender mal-adaptive behaviours. In virtue of the enormous upgrade that previously fixed adaptive solutions would gain with the fixation of a module of symbolic signification, our species could “allow itself the luxury” of fixing a mental feature that at least partially slipped the reins of natural selection. Plus the fact that it would enable us to establish formal social bonds no longer wholly determined by bloodline or linear reciprocity.

Coda

I would hate to think of the reader finishing this text convinced that human evolution is clear proof of the existence of a plan - a finalism - guiding the evolutionary process, when I have done my best to demonstrate the contrary. Precisely because it is so difficult to examine the evolution of any biological line retrospectively, whether animal or vegetal, without feeling the allure of teleology, twice in this essay I presented simple stories to show how apparently finalistic situations can be explained by the logic of chance and necessity inherent to the Darwinian evolutionary process, to use the words of the Nobel laureate Jacques Monod, one of the greatest champions of basic evolutionary concepts before the general public. This same logic can be applied to all the other moments of hominin evolution described herein, and I dearly hope the reader will.

Chance in biological evolution comes down to the existence or otherwise of variants in a population at the precise moment in which they could serve as source material for adaptive solutions. Variability depends on mutations that occur in a totally unpredictable manner in the genome. Necessity, for its part, concerns the survival challenges imposed by changes in the environment in its full sense, i.e., competitors included.

Both defy prediction. Chance is no guarantee of necessity, much less necessity a determinant of chance, which is precisely why so many evolutionary lines have become extinct over time, including hominin lines. The sense that it is all just too much of a coincidence fades before the realization, however modest, of just how many millions of evolutionary lines have actually fallen by the wayside: chance and necessity do not always occur in the same place and the right time.

Nor would I like the reader to come away from this text contaminated by what we call the “functionalist fallacy”, or, better put, the “adaptive fallacy”, even if the text itself may be impregnated with it in many ways. In our eagerness to present the basic logic of Darwinian theory (chance + necessity)

to a wider public, we scientists often end up over-simplifying the evolutionary process, robbing it of the nuances and even the inconsistencies that are fundamental to the maturation of the theory itself, if it is to remain this side of esotericism.

All too often we have the impression that adaptive bodily structures were fixed in response to the immediate necessity they met, so clearly does the cause/effect relationship appear to bear this logic out. They simply fit hand-in-glove. However, this perspective could lead some to conclude, as it were, that our ears and nose are positioned as they are because of our need to wear glasses. Of course we all know that the structural positioning of the human ears and nose was fixed millions and millions of years before the invention of glasses.

What I mean to point out is that a structure fixed in the distant past in response to a particular adaptive demand may be coopted later on, by pure chance, to serve another, totally different adaptive function. This is what we evolutionists call “exaptation”, a concept most fully fleshed-out in the 1970s by Stephen Gould.

The concept of exaptation has helped us understand many key evolutionary changes, such as flight in birds and the option of the first vertebrates to shift from water to land. We now know that feathers first emerged in certain dinosaur lines as a means of regulating body temperature, only to be coopted for flight millions of years later.

Many of the adaptive solutions I have described in hominin evolution may in fact have been exaptations rather than primary adaptations. One example is enough to sustain the affirmation: there is no longer any doubt that there is no causal relation whatsoever between the fixation of bipedalism (the freeing of the upper limbs from the task of locomotion) and the production of stone tools, as some five million years separate the two events. In other words, the adaptation toward upright walking, with the consequence of leaving the arms and hands free for other business, happened for some other reason that has absolutely nothing to do with toolmaking. And yet, once the arms were free from locomotion, they could be coopted millions of years later for a new task: the knapping of stone.

Up to the 1970s we did not know that bipedalism predated toolmaking by such a long time, so most authors, since Darwin himself, reckoned on a direct causal relationship between the fixation of one and the other. It seemed to make so much sense, the pieces fit so well, and then, only thirty years ago, we discovered it was a classic example of how the functionalist fallacy can cloud our understanding of a given evolutionary process.

Notes

- 1 The term ‘hominin’ refers to humans and our bipedal ancestors. Not to be confused with hominoids, a more inclusive group into which fall the gibbon, siamang, orang-utan, chimpanzee, gorilla and man, as well as all their ancestral fossils. For the sake of convenience, throughout the text, the orang-utan, chimpanzee and gorilla will be collectively referred to as “great apes”.
- 2 The great apes include the orang-utan (Asian), the chimpanzee and gorilla (African).
- 3 For more on this subject see Richard Dawkins’ *The Blind Watchmaker* and *Climbing Mount Improbable*.
- 4 South American capuchin monkeys are sometimes known to use one stone as an anvil and another as a hammer to break open fruits or nuts and expose their edible contents. In doing so, they momentarily free their hands by adopting a sitting posture. However, the importance of this strategy to their overall subsistence is unknown.
- 5 For more information on this subject, see “The Origin of Man”, by C.O. Lovejoy, published in *Science*, v211, p.341-50, 1980.
- 6 The transition from the Pliocene to the Pleistocene occurred around 1.8 million years ago.
- 7 In fact, the savannahs are rich in tubers, but these need to undergo a complicated detoxification process in order to become edible.
- 8 Today, specialists tend to reclassify specimens of *Homo habilis* and *Homo rudolfensis* within the genus *Australopithecus*, which is why I have opted for *Homo ergaster/erectus* as the first representatives of our genus.
- 9 The term Australopithecine is used here in a more ample form, encompassing all pre-*Homo* hominins, regardless of genus.
- 10 The evolution of the human mind leaves no doubt as to its modular character, composed of specialized intelligences.
- 11 See previous note.
- 12 Modern man had tried to leave Africa in at least two waves prior to his exodus after the creative revolution of the Upper-Palaeolithic. These attempts were, however, restricted to tropical regions.
- 13 In truth, recent findings in Africa, particularly in South Africa, suggest that the creative explosion of the Upper Paleolithic occurred on that continent as far back as 70 to 80 thousand years ago.

Suggestions for further reading:

ARSUAGA, J. L. *O colar do neandertal*. Em busca dos primeiros pensadores. São Paulo: Globo, 2005.

BOYD, R.; SILK, J. B. *How humans evolved*. New York: W. W. Norton & Co., 2006.

- BULLER, D. J. *Adapting Minds*. Evolutionary Psychology and the persistent quest for human nature. Cambridge: The MIT Press, 2005.
- HUBBE, M.; MAZZUIA, E. T. A.; ATUI, J. P. V.; NEVES, W. A. *A primeira descoberta da América*. Ribeirão Preto: Sociedade Brasileira de Genética, 2003.
- KLEIN, R. G. *The human career*. Human biological and cultural origins. Chicago: The University of Chicago Press, 1999.
- KLEIN, R. G.; BLAKE, E. *O despertar da cultura*. Rio de Janeiro: Jorge Zahar, 2004.
- LEWIN, R. *Evolução humana*. São Paulo: Atheneu, 1999.
- _____. *Human Evolution*. An illustrated Introduction. Oxford: Blackwell Publishing, 2005.
- MITHEN, S. *A pré-história da mente*. Uma busca das origens da arte, da religião e da ciência. São Paulo: Editora Unesp, 1998.
- PINKER, S. *Como a mente funciona*. São Paulo: Companhia das Letras, 1999.
- _____. *A tábua rasa*. A negação contemporânea da natureza humana. São Paulo: Companhia das Letras, 2004.

ABSTRACT - THE MAIN purpose of this essay is to demonstrate that, as with any other animal, *Homo sapiens* is also a natural product of a long process of fixation of several evolutionary novelties. Although the role of specific creatures in this evolutionary history may come to be changed by new fossil discoveries in the Old World, mainly in Africa, science has already a very clear idea of the main changes that were implicated in the process of changing an ape-like creature into us. The essay emphasizes the conservative nature of biological evolution and how natural selection selects among the available options, if any. As a consequence, natural selection is far from producing optimal solutions. The evolutionary post-facto designs are far from being intelligently conceived.

KEYWORDS - Human evolution, Paleoanthropology, Evolutionary Theory, Darwinism, Hominines.

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Translated by Anthony Doyle. The original in Portuguese is available at http://www.scielo.br/scielo.php?script=sci_issuetoc&pid=0103-401420060003&lng=pt&nrm=iso.

Received on 8.3.2006 and accepted on 5.4.2006.

Acknowledgements: to Darwin, for having existed and guided us out of the dark ages. To the monkeys, without whom Darwin would never have existed. To João Steiner, for the honour of being invited to contribute to this volume; to Danilo V. Bernardo, for his help in choosing the illustrations and with the composition of some of the figures; and to Silvana Cristina Silva and Eduardo Gorab for reading the first draft and making valuable suggestions for improvement. This article is dedicated to **Ruth Camargo Vassão**.

Source of the figures

Figure 1: modified from an image available at: <<http://www.ib.usp.br/leeh>>.

Figure 2A: modified from an original available at: <www.mammalogy.org>.

Figure 2B: available at: <http://www.nature.com/news/2000/000323/images/xray_200.jpg>.

Figure 2C: created by the author.

Figure 3A: available at: <www.nhm.ac.uk/.../july/images/lucy150_5980_1.jpg>.

Figure 3B: available at: <<http://www.skullsunlimited.com/graphics/gorilladisarticulated02.jpg>>.

Figure 3C: available at: <<http://www.boneclones.com/SC-092-D.htm>>.

Figure 4: skull available at: <www.talkorigins.org/faqs/homs/toumai.jpg>.

Reconstruction: modified from <<http://www.lemonde.fr/web/vi/0,47-0@2-3244,54-636614@51-627751,0.html>>.

Figure 5: modified from Lewin (2005, p.134).

Figure 6: Boyd and Silk (2006, 277).

Figure 7: *Forest*, available at: <<http://www.nationalgeographic.com/wildworld/images/profiles/terrestrial/at/sm/at0126a.jpg>>. *Woodland*, available at: <<http://www.rcfa-cfan.org/graphics/woodland.jpg>>. *Savannah*, available at: <<http://www.micro.utexas.edu/courses/levin/bio304/biomes/SAVANNA/savanna.html>>.

Figure 8: available at: <<http://www.he.net/~archaeol/online/news/jpegs/human/human3.jpeg>>.

Figure 9: modified from Boyd & Silk's original (2006, p.306).

Figure 10: modified from images in the Thomas van der Laan collection. Available at: <<http://www.ib.usp.br/leeh>>.

Figure 11: images from the Thomas van der Laan collection. Available at: <<http://www.ib.usp.br/leeh>>.

Figure 12: assemblage made from images available at: <http://www.mnh.si.edu/anthro/humanorigins/ha/ances_start.html>.

Figure 13: image from the Thomas van der Laan collection. Available at: <<http://www.ib.usp.br/leeh>>.

Figure 14: image available at: <http://www.mnh.si.edu/anthro/humanorigins/ha/ances_start.html>.

Figure 15: assemblage made from images from the Thomas van der Laan collection. Photos available at: <<http://www.ib.usp.br/leeh>>.

Figure 16: image assembled from Boyd & Silk's originals (2006, p. 357).

Figure 17: assemblage made from images from the Thomas van der Laan collection. Photos available at: <<http://www.ib.usp.br/leeh>>.

Figure 18: Boyd & Silk (2006, p. 394).

Figure 19: image available at: <<http://www.educarchile.cl/autoaprendizaje/biologia/modulo5/clase1/img/sapiens/7.jpg>>.

Figure 20: image from the Thomas van der Laan collection. Available at: <<http://www.ib.usp.br/leeh>>.

Figure 21: image from the Thomas van der Laan collection. Available at: <<http://www.ib.usp.br/leeh>>.