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# The Final Wave:
# *Homo sapiens* biogeography and the evolution of language

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**Abstract** Considering recent data coming from different disciplines like molecular biology and palaeontology – handled as elements of an inference towards the best explanation – here we explore the hypothesis that the development of a fully articulated language favoured key cultural innovations, which in turn pushed the last population wave of *Homo sapiens* out of Africa about 60 to 50K ago. Human biogeography could be the keystone for the correct interpretation of the fragmentary data concerning the so-called "Paleolithic Revolution". It is possible that the "final wave" of people out of Africa after the period of 60K, associated with the L3 haplogroup, was the bearer of the behavioural innovations which until now have been associated with the symbolic revolution. In "The Final Wave" model, the evolutionary process is continuous, but with punctuated bursts of innovations in small populations; there is a direct liaison between biological evolution and cultural evolution (with the latter grafted onto the former); a growing interdisciplinary collection of evidence is unified in a frame stressing the role of biogeography in the evolution of cognitively modern human behaviour.

**Keywords:** Paleolithic Revolution; Waves Out of Africa; *Homo sapiens* biogeography; exaptation; bursts of cultural innovation

When we observe the wonderful results of the so-called "Paleolithic Revolution", everyone is driven to associate them with a global reorganisation of human cognition and behaviour. For the first time, a human species is able to show, in a systematic and no longer episodic way, the complete and unprecedented package of intellectual modernity (KLEIN and EDGAR 2002). Around 45 to 40K ago (K signifies up to 1000 years), as well as being anatomically modern we developed a modern mind and the ability to exercise symbolic and abstract thought: extraordinary cave paintings, enlivened by realistic hunting scenes, symbolic and stylized figures; exquisite works of art carved in bone; sophisticated ritual burials; body ornaments, jewels and embellishments; the first musical instruments, new technology for stone working – initially Aurignacian and then rapidly diversifying according to distinct regional cultures; and the construction of more complex shelters, even in open spaces (TATTERSALL 1999).

A new species is in action: one imagining itself, asking questions about the surrounding nature and its patterns: seasons, tides, moon cycles, and plant and animal yearly rhythms. Except for a few sporadic hints there are no comparable explosions of creativity in the other four species that lived at the same time as *Homo sapiens*. As Tattersall pointed out, it is as if we had learnt to imagine possible worlds inside our heads, instead of passively accepting the harshness of nature as it was (TATTERSALL 2009a). A new modern human mind was born, ready to explore new paths, such as art, music and dance, using artefacts and behaviours as marks or signs of something else (in this sense here we intend the blurred term "symbolic") (ACZEL 2009). Splendid *Homo sapiens* burials discovered in Sunghir, dated to 30–28K ago, display all the creativity of the Palaeolithic revolution and the first sharing of beliefs. An unprecedented form of human intelligence is able to devote long hours to make objects of beauty that had no immediate practical purposes for survival, but which had become part of the symbolic life of the *Homo sapiens* society.

## 1. The double birth of *Homo sapiens*

Who were the humans that were able to do all that? What evolutionary novelty triggered this behavioural change? Was it a punctuated global innovation or the culmination of a slow evolutionary trend? Here we are going to present a model that could make this question old-fashioned. One of the most interesting unanswered questions of our evolution is the time mismatch between the appearance of *Homo sapiens* species and the cognitive abilities of its members. Why was the Palaeolithic Revolution so late, at least in its more systematic version?

The time gap is possibly just an illusion due to a lack of evidence or to long periods during the Glaciations when the human population shrunk in numbers. Other experts believe our species always had the physical and cerebral potential to display such behaviour from the onset, but that for reasons due to changes and previous adaptive needs a trigger was needed to release these resources. This process of "functional co-opting" is known by evolutionists as exaptation, whereby a structure evolved for a certain function (pre-adaptation) or as a side-effect of others (spandrel) is then re-used for new functions in subsequent contexts (GOULD and LEWONTIN 1979; GOULD and VRBA 1982; PIEVANI 2003; PIEVANI and SERRELLI 2011).

Considering recent data from different disciplines like molecular biology and palaeontology – handled as pieces of a puzzle and elements of a model intended as an inference towards the best explanation – here we are explore the possibility that the development of a fully articulated language favoured the key cultural innovations which in turn pushed the last population wave of *Homo sapiens* out of Africa about 60 to 50K ago. So, there could be a causal correlation between the evolution of the specific language of *Homo sapiens*, the symbolic behaviour and the geographical globalisation of human populations (CAVALLI SOFRZA and PIEVANI 2012). Human biogeography could be the hidden side of a story that still needs to be completely disclosed by science.

Let us start from the beginning of our species. Eight thousand generations ago (about 200K ago) the first *Homo sapiens* made their appearance in sub-Saharan Africa, during the umpteenth dry phase which coincided with the last Quaternary Ice Age. It was a small population with some identifying traits such as a tall and slim build, large skull and cranial capacity (exceeding 1400 cc), good stone working skills and different modulation of gene expression regulating our extended growth and development phases, longer than any of those found in any other *Homo* form (GOULD 1980; BRUNER, MANZI and ARSUAGA 2003).

The timeline of human relationships deduced by molecular data (mt-DNA and Y chromosome) since 1987 shows the older African populations and the later splits between African and Asian peoples, and later between Asians and Europeans, Asians and Australian aboriginals, and between everyone else and the American Indians (CAVALLI SOFRZA, MENOZZI and PIAZZA 1994; CAVALLI SFORZA 2000). Confirmation also came from paleontological data: *Homo sapiens* differentiated in sub-Saharan Africa from the more ancient populations, possibly *Homo heidelbergensis* in the African version. Early archaeological finds of African *Homo sapiens* whose traits were slightly more primitive than their descendants' are consistent with genetic data and come from the Omo Valley in Ethiopia. They go back to 195K ago. Later finds, belonging to the "idaltu" variant were discovered in Herto Bouri, in the Middle Awash, the region of the Afar, and trace back to 160–154K ago. In South Africa the first known specimens of *Homo sapiens* could also be very old, maybe dating back to 164K ago. So the birth of *Homo sapiens*, as an anatomically distinct species, seems much older than the second one, the birth of cognitively modern humans. Is it therefore possible to fill up this gap?

Again, the first signs of symbolic behaviour come from Africa, and not from Europe as thought for a long time: in Blombos Cave, south of Cape Town, there are 75K old pieces of ochre with engravings organised in a pattern, as if a computation or a stylized figure. In other South African sites traces of ochre and decorative shells have been found, probably really ancient. Much later, in Europe, in Cro-Magnon *Homo sapiens* new and extremely innovative behaviours emerged. So it seems that we have a first "burst" of innovation in South Africa (or several bursts there), and much later new innovations with the arrival of the first *Homo sapiens* in Europe and Australia. Geography could be the keystone for the right interpretation of these fragmentary data.

## 2. In search for the trigger of human specificity

If we compare the degrees of early specificity in *Homo sapiens*, approximately between 200 and 120K ago, we see quite low levels of technological innovation (for a long period Middle Paleolithic stone tools were almost like the Neanderthal ones), low in social organisation (with just episodic significant innovations), absent in specific genetic mutations possibly connected to articulated language like FOX-P2 (the only two mutations derived, with respect to chimps, are shared with Neanderthal – KRAUSE et al. 2007), absent in specific morphological change possibly connected to articulated language like in the hyoid bone (the same in Neanderthal, and both different from *Homo erectus* – CAPASSO, MICHELETTI, D'ANASTASIO 2008).

Instead, we see three evident marks of high innovation: 1) in the global anatomy, uniquely derived mostly in the structure of the skull and postcranial skeleton; 2) in the maximum of neotenic trend observed in dental and skull development (also compared with Neanderthal: a study on teeth which finished in 2011 has shown that their development was slightly faster than ours, although not all data are consistent – SMITH et al. 2010), associated with a supposedly extended genetic re-organisation; 3) and mainly, in the very peculiar pattern of distribution of genetic diversity, a hint that was until now underestimated but has long-ranging bio-geographical consequences: genetic diversity inside our species is less than in any other primate (KAESSMANN et al. 2001).

The explanation for this low level of genetic diversity inside the species could be related to the presence, in our natural history, of one or more evolutionary "bottlenecks": a drastic reduction in population numbers, leading to the brink of extinction and then the few survivors starting up again after the cataclysm, with a robust population expansion. We have two main bottleneck-hypotheses discussed in the field, but a third one could be added. Molecular data show a possible fall in *Homo sapiens* numbers around 70–75K ago, in coincidence with a drop in world temperatures due to the "volcanic winter" caused by the catastrophic eruption of Toba on the Isle of Sumatra, a global environmental disaster (for a critical review: GATHORNE-HARDY and HARCOURT-SMITH 2003).

Other experts believe that the bottleneck (or one of them) took place earlier on in Africa during the Ice Age which stretches from 190 to 123K. Because of the changes in the winds and rainfall, glaciation led to arid zones increasing in Africa. According to a growing amount of data coming from South African sites, the few *Homo sapiens* may have found seaside refuges on the more welcoming coastlines of the Cape in South Africa, the Southern tip of the Rift Valley (MAREAN et al. 2007).

So, in at least one phase of our evolutionary history there were really very few of us (HUFF et al. 2010), but it is very hard to find reliable connections between specific climatic changes and demographic oscillations. A third hypothesis, related to bottlenecks produced by the repeated waves of *Homo sapiens* out of Africa, is gaining consensus. There are currently seven billion human beings on the planet and they have very limited genetic variance, proportionally less as one shifts away from the African continent (RAMACHANDRAN et al. 2005). This suggests that the entire human population could descend from a small initial group which contained all our ancestors and which is thought to have numbered just a few thousand.

Later this original pioneering population which originated in the sub-Saharan grew and spread, radiating new small founding groups which 60–50K ago populated first the Old World, then Australia and the Americas, as inferred now from genome-wide patterns of variation (LI et al. 2008). The dynamics of expansion through subsequent shifts from the outer rim of the previous population generates a sequence of genetic drifts, an evolutionary step whereby the greater the distance with Africa, the fewer the average inner differences in any group of humans.

This model, proposed by a network of geneticists led by Cavalli Sforza, is known as the "serial founder effect", originating in Africa (DESHPANDE et al. 2009). When a small population separates and "drifts" either because of a physical barrier now separates it from its original territory or because some of the founders leave and colonise another land, the few that leave carry a random portion of the variation present in the original population. They will be genetically a little poorer and with particular variations which can develop in unprecedented percentages: for instance some genetic traits like blood groups may prevail, or certain hereditary diseases can vary in frequency. The genetic effects on variability are much the same as in a series of multiple "bottlenecks". Furthermore, in a small group normal frequency oscillations of variants can more easily lead to the prevalence of some traits and to the disappearance of others.

This correlation highlights how genetic diversity decreases due to the serial founder effect, as populations moved away from the African continent. Geographical distance is calculated as a straight line, considering oceans and the main physical barriers where no alternative routes are available. With a sequence of colonies *Homo sapiens* virtually covered 25,000 km, that is the distance which separates Addis Ababa to the southern tip of South America. The model – proposed by Deshpande, Batzoglou, Feldman and Cavalli Sforza (2009) – is based on the assumption that people move short distances to reproduce and that genetic exchanges between neighbouring populations do not weaken the effect of the genetic drift.

So, we now have two main results from human genetics: 1) a positive and strong correlation between the decrease in genetic variability and the distance from Africa; 2) human genetic diversity has a geographical maximum. In 2010 a group of geneticists completed a project on the genome of four elderly Bushmen hunter gatherers, compared with a famous scion of Bantu farmers, archbishop and Nobel Peace Prize winner, Desmond Tutu (SCHUSTER et al. 2010). The average individual variability among these South African genomes was extremely high. In particular, khoi-san languages speakers seem to be the closest to the initial phases of human diversification and spread: “Hunter-gatherer genomic diversity suggests a southern African origin for modern humans” (HENN et al. 2011). This highest degree of diversity in a specific region indicates that new genetic variations have been able to accumulate over a very long time there: “African hunter-gatherer populations, with a maximum in southern Africa, continue to maintain the highest levels of genetic diversity in the world” (ibid.).

## 3. Multiple waves of *Homo sapiens* globalisation: the great picture

So we can now see the global picture of human global settlement, as inferred until today from molecular and archaeological data. From an area possibly close to the Eritrean site of Abdur, where the presence of *Homo sapiens* dates back to 125K, the multiple dispersion of our species out of Africa began. Our species probably left the continent in several waves: 1) the first wave (subsequently interrupted) 120–100K ago transited directly from the Horn of Africa to the Bab el-Mandab Strait, and possibly across a more Northern route, that is to say along the Red Sea and the corridor of the Nile, up to the Mediterranean and towards the Levant crossing the Sinai peninsula; 2) a second wave followed the same two routes, between 85 and 50K ago, moving into Asia; 3) a third and more stable wave occurred with a favourable climate, between 60 and 50K ago.

Around 50 to 45K ago *Homo sapiens* from the east and possibly from the South East walked into Europe, forming a people with very advanced behaviour, called Cro-Magnon. In that phase they were also found in the inner Asian regions, on the edge of Northern steppe, and in the Far East, in Zhoukoudian (China) where they arrived 67K ago. Stone working technologies of the first *Homo sapiens* out of Africa were innovative, but initially like the ones of the other contemporary species: blades, scrapers and points by flint knapping striking chips from a prepared core (the so-called Levallois technique). In Levantine sites like Skhul Cave, it is possible that some perforated marine shells are even 100K old. But an important hint is that, beginning 60–50K ago, the Levant *Homo sapiens* techniques became rapidly more refined in a systematic way. Intentional burials and abundant perforated marine shells are associated. Interestingly, we are here in an intermediate period between South African and European innovations: is this evidence of gradualism? Or early, failed “experiments”? Those remains could be possibly connected with a later wave of diffusion out of Africa, after a period of local bursts of innovations.

This later and increased attitude to the expansion in *Homo sapiens* seems to have peculiar features also for other reasons. Between 60 and 50K ago, to reach the Australian supercontinent a 70–100 km channel had to be forded or sailed to pass

Timor or Sulawesi. At such a distance it is difficult to see the other shore. Some *Homo sapiens* tribes forded the sea stretch and were successful, very probably more than 55 and 50K ago since a few thousand years later they could be found both on the Bobongare shoreline in Eastern New Guinea and on Lake Mungo in New South Wales in Australia. The people involved in this new adventure of human colonisation showed advanced behavioural and cognitive skills.

The ancestors of the aborigines used elaborated technologies and displayed a strong aesthetical awareness, showing signs of local innovations (TUNIZ, GILLESPIE and JONES 2009). A few millennia after their arrival, at the antipodes compared to Cro-Magnon Europe, they had produced a lively symbolic and artistic system. They were skilled hunters and – on their own or possibly with the help of the climate – they contributed to the extinction of the Australian mega-fauna. All this happened at least 30K before the earliest vessel sailed the Mediterranean, and even before the European symbolic revolution of the Cro-Magnon people. So, the minds of the first human beings that reached Australia were extremely creative. And the new dates of the first Australian settlement fall in the period of the later expansion of *Homo sapiens* out of Africa.

We see the same story in another great frontier of the *Homo sapiens* voyage, the North Eastern Passage towards the Americas. The oldest hunter gatherer society so far discovered in eastern Siberia is the Dyuktai which goes back 35K. It may have been 25K ago when Siberian hunters crossed Beringia and settled there, to then move on in pursuit of the mammoth and caribou herds, and descended into North America, both along the Canadian Saint Lawrence Corridor and along the rugged Northern Pacific coast line rich in fish. With the end of the last Ice Age and the arrival of the first hunters from the so-called Clovis civilisation about 13K ago, fifty seven species of large size mammals became extinct in North America, followed by an even larger number in South America. As in Australia, another "type" of humans – cognitively skilled, socially organised and more invasive – seems to have been in action here.

## 4. Punctuated bursts of innovation, and then a final wave out of Africa

Where did they come from? According to Jacobs and Roberts (2009) and their highly sophisticated methods of systematic dating of several sites in southern Africa, "two bursts of human innovation in southern Africa during the Middle Stone Age may be linked to population growth and early migration off the continent". Thanks to the analytic reconstruction of geography and timing of the two cultures of Still Bay Points (between 71 and 70K ago) and Howieson's Poort Points (between 65 and 60K ago), they outline the "ephemeral and punctuated nature of these bursts of technological and behavioural innovation" (JACOBS and ROBERTS 2009).

The study is really innovative, because Jacobs and Roberts integrate biogeography, systematic dating, ecology, climate science and molecular data in new kinds of regional survey (JACOBS et al. 2008). They believe that repeated pulses of demographic expansions and contractions, produced by environmental local changes (and not by the catastrophic ones presumed in drought hypothesis and Toba hypothesis), influenced the social networks and the capacity of cultural innovation in small groups of *Homo sapiens* during the Middle Stone Age in southern Africa. The symbolic behaviour could have originated in such a complex scenario of evanescent cultures associated with little hunter-gatherer populations.

But what is even more interesting is that these data seem coherent with molecular ones. Their results "hint at the possible role of population expansions in Africa as a trigger for these Stone Age innovations, and, maybe, for early migrations from Africa about 60K ago" (Jacobs and Roberts 2009). In fact, "all mt-DNA lineages found outside Africa derive from just two haplogroups (M and N) that descend from L3 haplogroup" (ibid.), and the youngest major African L3 haplogroup corresponds to an increase in population size between 86K and 61K, so a time span exactly including the Still Bay and Howieson's Poort cultures. Why did only one haplogroup (among the major four indigenous to Africa) show this success? According to Atkinson, Gray and Drummond (2009), forms of cultural innovation and increases in behavioural complexity by members of the L3 haplogroup gave them a competitive advantage in terms of group coordination, technological and communication efficiency, and mainly social cohesion (PIEVANI 2011a).

Expansions were the trigger for innovations, and vice versa, because technological and behavioural innovations needed an extended network of social contacts and exchanges to be spread. In other phases, population contractions isolated smaller and fragmented hunter-gatherer communities, breaking the social and economical networks: that is why we see several bursts of ephemeral and local innovations, lasting just few millennia. So, the geographical dispersion and the population size of the groups are two underestimated and crucial factors, with threshold-effects on behavioural innovation. In this scenario, Jacobs and Roberts suppose that "a spark of human ingenuity" inside the groups of L3 carriers in East Africa was the catalyst for the ring cultural innovation-demographic expansion in a group with unprecedented success:

> that innovation encouraged social cohesion and the more efficient use of natural resources, prompting rapid population growth among this group of people. This population expansion may have, in turn, promoted more innovations, including the Still Bay and Howieson's Poort in southern Africa, and the migration of people out of Africa to the north (JACOBS and ROBERTS 2009: p. 309).

A new model of modern human prehistory is emerging: it is possible that the "final wave" of people out of Africa, after the period of 60K, associated with the L3 haplogroup, was the bearer of the behavioural innovations that until now are associated with the so-called "symbolic revolution". As suggested by Cambridge archaeologist Mellars (2006), after the first dispersals of anatomically modern populations to Asia between 110 and 90K ago, major technological, social and economic changes occurred in Africa between 80 and 70K ago, associated with clear symbolic expressions, in a period of climatic and environmental changes. Those changes were followed by major population expansions in Africa from small source areas (like in Still Bay and Howieson's Poort cultures) between 70 and 60K ago, and then by the dispersal of modern populations from Africa to Eurasia around 60K ago. Now to the interdisciplinary circumstantial evidence gathered so far we can add further substantiation.

## 5. Causes and consequences of the final wave

When the final wave begins to spread through the old world, and then into the new ones, we were not alone. At least another three human forms, descended from previous expansions, populated Eurasia: *Homo neanderthalensis*, *Homo floresiensis*, and the hominins from Denisova. Skilful hunters, with advanced technologies, social complexity and different cognitive worlds, they were specialised and well equipped species of humans in their environments. We lived side by side with the Neanderthal for a long time: for tens of thousands of years we shared some of the same habitats, from the Asian steppes to Southern Europe, in a scarcely populated world (Gibbons 2010). Even possible regional hybridisations are under discussion in the cases of Neanderthals and Denisovans with *Homo sapiens* in Asia (PIEVANI 2011b).

However when the “final wave” of *Homo sapiens* arrived, after 50–40K ago, the demographic balance with other human species clearly inclined in our favour. Neanderthal became extinct in the Iberian Peninsula around 30K ago, and *Homo floresiensis* 12K ago in the island of Flores. We know episodic expressions of symbolic behaviour in Neanderthal, but nothing compared with the systematic change in global behaviour and the cultural innovations observed in the later *Homo sapiens* populations during their diffusion in the Old World. The extinction of any other human species and the emergence of the complete modern human behaviour in *Homo sapiens*, with the trigger of the self-catalytic ring between expansion and cultural innovation, could be two causally related evolutionary phenomena: our species became more demographically invasive and increasingly competitive.

*Homo neanderthalensis* might have had a basic form of articulated language, as shown by his hyoid bone. Gene FOXP2, which regulates the embryonic development of neural structures – including those of motor control and language articulation – has the same sequence both in *Homo sapiens* and Neanderthal. However a gene and a little bone are not enough to speak: the overall structure is paramount (Lieberman 2006) and the linguistic faculties originated from a long Darwinian evolution of pre-linguistic competences in social learning and the production of tools (MANZI and DI VINCENZO 2012). According to Lieberman and McCarthy (2007), *Homo sapiens* was the first to display the complete typical right angled vocal tract: that is the lengthening of the vertical section – larynx, vocal cords and pharynx – becoming the same as the horizontal section – palate to lips. This special conformation is peculiar to humans, making possible a vast range of sounds, modulating all the consonants and vowels of a modern language. Harsher climates and the need to protect their throats meant Neanderthal necks were too short compared to the horizontal cranial lengthening, even in specimens associated with Middle Palaeolithic stone tools (70 to 40K ago).

But what is really surprising is Lieberman and McCarthy’s discovery that there is a meaningful difference in speech physiology between the vocal trait of an early *Homo sapiens* specimen (100K ago) from Israel, associated with Middle Palaeolithic stone tools, and the vocal trait of eight *Homo sapiens* specimens from the Upper Palaeolithic (40 to 10K ago), associated with more complex Upper Palaeolithic stone tools. The former has “an extremely short neck”. So, probably the vocal trait of our species was not complete in the early phase of our speciation, 200K ago, with a horizontal portion that was still longer than the vertical one.

Again, we have further evidence able to fill up the gap between the first *Homo sapiens* and the appearance of people who settled the world through multiple waves out of Africa, probably bearing a complete and systematic symbolic behaviour. If only the more recent *Homo sapiens* (40 to 10K ago) were able to produce the full range of speech sounds available to humans today, it is very suggestive, even if still speculative, to suppose that fully modern speech was the key innovation of the final wave of humans spreading out of Africa. As Lieberman and McCarthy pointed out in their final remarks:

> It was only in our reconstruction of the most recent fossil specimens – the modern humans postdating 50,000 years – that we identified an anatomy that could have accommodated a fully modern, equally proportioned vocal tract. Interestingly, the date of these specimens coincides with the appearance of the Upper Paleolithic tool kit, which is often associated with a florescence in modern human cognitive capacities (LIEBERMAN and McCARTHY 2007: p. 20).

And we can now add: which is also associated with the final wave of the global spread of modern human populations from Africa, belonging to L3 mt-DNA haplogroup and its descendants, that those humans had a brain so similar to ours which "possessed not only the capability to produce languages with complex syntax, but also cognitive flexibility" (ibid.). A completely articulated language, with its cognitive and social consequences, could be the specificity of our final wave.

## 6. Language: our secret weapon?

Other recent scientific results reach the very same conclusions, from a different perspective and convergent evidence. The population of the planet led to a further diversification of human groups, some of which no longer communicated with one another because of the enormous distances. This could have produced a corresponding linguistic diversification. As we know, the evolutionary tree of the linguistic families matches the genetic evolution of populations surprisingly well (CAVALLI SFORZA, MENOZZI and PIAZZA 1994). The separation and repeated movements of human groups into new territories may have generated a series of "founders" who then accumulate small genetic and linguistic differences because of a lack of contact or exchanges with the original population. In the long term, this may lead to major genetic diversity between the two groups and to the development of corresponding linguistic "branches". This is why the maps of population and linguistic families in the world basically match.

So, the transmission of languages and genes are interestingly alike. However there are also great differences between the two trees: linguistic innovations have more channels of transmission compared to genetics and above all they can spread to people who are in no way related. Cultural mutations are intentional and languages evolve more rapidly than genes and a few hundred years can turn one language into two or more. Above all, genetic drift is always random while language changes can be influenced by social factors, such as the power and territorial expansion of a dominant elite (PIEVANI 2011c).

These analytical and substantial differences between the two processes the result presented by Atkinson in April 2011 in *Science* make even more surprising: "Phonemic diversity supports a serial founder effect model of language expansion from Africa" (ATKINSON 2011). As we have seen, "human genetic and phenotypic diversity declines with distance from Africa, as predicted by a serial founder effect in which successive population bottlenecks during range expansion progressively reduce diversity, underpinning support for an African origin of modern humans". Applying an analogous statistical analysis to the diversity of phonemes (the basic units of sound that differentiate words), it appears that a similar pattern may operate on human culture and language: "the number of phonemes used in a global sample of 504 languages is also clinal and fits a serial founder effect model of expansion from an inferred origin in Africa. This result, which is not explained by more recent demographic history, local language diversity, or statistical non-independence within language families, points to parallel mechanisms shaping genetic and linguistic diversity and supports an African origin of modern human languages".

So, surprisingly the point of view of genes and the point of view of phonemes tell the same story of human diversification. Some linguistic caveats need attention: 1) the unique origin of modern languages is not proven in this way; 2) phonemic diversity is a weak statistical basis because it varies inside the languages in a wide range of regional variants (other methodologies are expected: through regional variants, or units of syntax); 3) the differences between biological evolution and linguistic evolution cannot be underestimated. However, the provisional matching of the two patterns is impressive, mostly because the evolution of language is associated for the first time to *Homo sapiens* biogeography.

According to Atkinson, the connection between language and the global expansion of cognitively modern humans is clear:

> Truly modern language, akin to languages spoken today, may thus have been the key cultural innovation that allowed the emergence of these and other hallmarks of behavioural modernity and ultimately led to our colonization of the globe (ATKINSON 2011: p. 348).

As Pagel incisively pointed out in his comment to Atkinson in *The New York Times*:

> "Language was central to human expansion across the globe. It was our secret weapon, and as soon we got language we became a really dangerous species"
> (in WADE 2011)

So, let us summarise the headlines of the model here proposed. It is a revised version of the "exaptive hypothesis" about the emergence of cognitively modern humans (TATTERSALL 2009b), not involving a discontinuous and very recent "great leap forward" without geographical reference. The model shows three main evolutionary phases:

1) Emergence of genetically and anatomically modern populations in Africa (with the enabling equipment or "exaptive" potential – 200 to 80K ago):
  - anatomic innovation (a tall African species);
  - neotenic trend (reorganisation of gene expression; new neural substrate; influences on social organisation and language);
  - first waves out of Africa (southwest Asia);
  - episodic expressions of symbolic behaviour.

2) Punctuated bursts of cultural innovation in Africa (80 to 60K):
  - climate instability (pulses of demographic expansions and contractions);
  - earliest evidence of systematic symbolic behaviour in Africa;
  - complete evolution of vocal trait (enabling fully articulated language).

3) Rapid geographic diffusion of cognitively modern humans, the "final wave" (60 to 50K ago):
  - spread of modern complex languages in Africa;
  - geographic (L3 haplogroup) and cultural diffusion in Eurasia and then Australia and Americas;

- expressions of the “Paleolithic revolution” in Europe and Australia;
- cultural adaptations and diversifications;
- broad hunting and extinction of mega-fauna;
- demographic substitution of all the other human species or forms.

In this model, based on a pluralistic and extended version of the Neo-Darwinian theory of evolution (PIEVANI 2012): A) the evolutionary process is continuous, but with punctuated bursts of innovations in small populations; B) there is a direct liaison between biological evolution and cultural evolution (with the latter grafted onto the former); C) a growing interdisciplinary collection of evidence is unified through an inference towards the best explanation, stressing the role of biogeography in the evolution of cognitively modern human behaviour.

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