Major evolution of the human brain correlated with tool-making leap

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A central question in the study of human evolution pertains to when, and of course how and why, modern human cognitive abilities evolved beyond those of our ape progenitors. New research sheds light on the timing of this process. In a just published article in the journal *Science*, an international team of researchers, led by Marcia S. Ponce de León of the University of Zurich, has found that modern-looking human brains appeared by about 1.7 to 1.5 million years ago as compared to the earlier, more primitive brains of the first members of the genus *Homo* .

This is significant because the earliest known members of the genus *Homo* date back a million years earlier, to approximately 2.8 million years ago. These earlier humans had already dispersed out of Africa into Eurasia by 2.1 million years ago and had been making primitive core and flake stone tools known as Oldowan since at least 2.5 million years ago, despite their more primitive brain configuration. Therefore, this new research indicates that the first migration of humans into Eurasia was accomplished by populations not possessing modern human cognitive skills, later to be followed by more modern humans, also coming from Africa.

For obvious reasons, the behavior and cognitive abilities of extinct humans cannot be directly observed. Scientists must rely on proxy measures, including artifacts and physical anatomy, to infer these characteristics. Both have limitations, however.

The material remains in the archaeological record for early humans consists almost exclusively of stone tools, while artifacts, food remains and other objects composed of organic materials have largely disappeared. While stone tools can provide insight into cognitive abilities based on the technological sophistication of the manufacturing process and, perhaps even the structure of language, much of the richness of modern human capabilities remains unobservable.

The other main source of data for investigating early human cognitive abilities is the comparative anatomy of the brain. Unfortunately, given that the brain consists of soft tissue, it does not usually fossilize. Therefore, the deep structure of the brain is inaccessible in the fossil record. However, the outer configuration of the brain leaves an impression on the interior of the skull. By creating casts, either physical or by digital imagery, of the inside of fossilized skulls, known as “endocasts,” not only the overall size, but the outer form of major regions of the brain can be studied.

The brains of modern humans are markedly different from those of great apes, both in overall size and in the configuration of various regions, giving some indication of the condition of our common ancestors. This is especially true of the frontal lobe, which is the region where complex cognitive processes, such as social skills, tool making and language, reside.

Members of the first hominin genus, *Australopithecus*, had brains that, in size and outward appearance, did not differ greatly from their ape ancestors. Indeed, the brains of early *Homo* were still largely ape-like, about half the size of those of modern humans. It must be remembered, however, that internal changes in brain architecture and, therefore, mental abilities, are likely to have occurred in early hominins which are not discernable in the endocasts, as evidenced by the production of stone tools. Also, the number of usable specimens dating to earlier than 1.8 million years ago is quite small, making detailed examination of changes over time difficult.

The new research is based on the examination of fossil skulls from Africa, the republic of Georgia (the

site of Dmanisi) and the Indonesian island of Java, which revealed that the modern configuration of the brain had only appeared by about 1.7 to 1.5 million years ago. The Dmanisi fossil skulls (five individuals) represent an early *Homo* population (the species identification is in dispute), dating to between 1.85 and 1.77 million years ago, and, therefore, provide a good baseline against which to compare the later fossil specimens from Africa and Indonesia, identified as belonging to *Homo erectus* .

Specimens from Africa dating between 1.7 to 1.5 million years ago show a mix of primitive and derived (i.e., more modern) characteristics of the brain, including a general increase in size, most notably of the frontal lobe, whereas later fossils consistently exhibit the more modern configuration. This strongly suggests that this transition first appeared in African populations of *Homo*. Specimens from Indonesia with the more modern brain configuration are less than 1.5 million years old, supporting the interpretation that they represent a "second wave" of migration out of Africa.

Among the changes observed in the more recent specimens is the enlargement of what is known as Broca's cap, part of the frontal lobe, which is linked to speech production. It is significant that the appearance of a more sophisticated stone tool technology, known as the Acheulean, occurred at this same time, replacing the older and more primitive Oldowan technology, which is associated with the Dmanisi fossils as well as earlier members of the genus *Homo* .

The Acheulean assemblage is characterized by the production of symmetrical biface tools, also known as handaxes, which require a much more complex manufacturing technique and associated mental capabilities than was previously employed to produce Oldowan tools, which consists of simple cores and flakes. Furthermore, Acheulean tools exhibit functional specialization not seen in the earlier technology.

The contemporaneity of these developments supports the hypothesized correlation between the evolution of language and technology, both requiring the capacity for abstract thought. This is also the time period of the earliest known adaptation of a particular feature of the human hand thought to be associated with sophisticated tool manufacture. The specifics of the dynamic between these developments remains an area deserving much more research. Clearly, however, a revolutionary advance in human evolution took place at between 1.7 and 1.5 million years ago. All three of these developments are first known to have appeared in Africa.

These results support two findings. First, that significant reorganization of the human brain took place later than the transition from *Australopithecus* to *Homo*, contrary to previous proposals (though some as yet undetectable changes are likely to have occurred at that time, as suggested by the development of Oldowan tool technology—the first known).

Second, the interpretation that there were at least two early waves of human dispersal out of Africa—the first wave, as early as 2.1 million years ago, consisting of early members of the genus *Homo (H. habilis* or very early *H. erectus*), having relatively primitive brains, and limited language and technological skills, followed by more modern humans with developed mental and practical capabilities. The question of whether the second wave replaced or merged with members of the first wave is yet to be determined.