Modern Human Origins Under Close Scrutiny

A wealth of fossil and genetic evidence is being interpreted to imply a recent African origin for modern humans, a conclusion that has important implications in anthropology

THE origin of anatomically modern humans, *Homo sapiens sapiens*, has recently become a hot topic in paleoanthropology, fueled as it has been by a combination of new fossil and genetic evidence. Compared with earlier periods in human evolution, which are often represented by a frustrating sparsity of fossil and archeological material, this last major event is blessed with wealth of cogent evidence. If any problem in human evolution is resolvable with the data currently available, then surely this is it.

On page 1263 of this issue Christopher Stringer and Peter Andrews of the British Museum (Natural History), London, present the first major review of the fossil and genetic evidence relating to the origin of modern humans. Without being dogmatic, Stringer and Andrews conclude that the collective evidence "favors a recent African origin for *Homo sapiens*," thus crystallizing what is becoming a popular, but by no means universal, view.

Opinions have ebbed and flowed over the decades, with, until recently, a strong Eurocentric flavor to it all. The 30,000-year-old Cro-Magnon people of southwestern France long epitomized what it meant to be modern humans. They made a sophisticated stone tool technology, which was characterized by fine blades, and went on to create carvings and cave paintings that dazzled prehistorians. This period came to be known as the Upper Paleolithic, a phrase that soon was synonymous with the emergence of modern humans. Implicit in this view was that modern humans could be recognized as much by their cultural products as by their anatomy.

The Neanderthal people have also dazzled prehistorians, not only because the fossil record for this prehuman species is the richest by far, but also because they appeared to have buried their dead with ritual, a very human behavior indeed. And the big question about the Neanderthals was, how did they relate to modern humans? Were they directly ancestral to *Homo sapiens*? Or were they a distinct branch of the human evolutionary tree that ended in extinction and contributed nothing to modern humans? Neanderthals' current biological designation as *Homo sapiens neanderthalensis*—a subspecies of *Homo sapiens*—reflects the sentiment of the past several decades that we are exceedingly closely related to them, probably as direct descendants.

In their assessment of the fossil and genetic data, Stringer and Andrews effectively designate Europe as something of a backwater as far as the origin of modern humans is concerned. And they categorize Neanderthals as having contributed little or nothing to modern human populations. The most recently published evidence—some of which appeared only in the past couple of weeks—strengthens this view.

Until recently, specimens of Neanderthal pelvises were incomplete, but it seemed that the pelvic outlet was bigger than in modern humans. This observation encouraged the speculation that Neanderthal babies were bigger than those of modern humans, born perhaps after a longer gestation period. However, when Yoel Rak and his colleagues at Tel Aviv University recently examined a virtually complete pelvis from the Kebara cave in Israel it turned out that the outlet was simply a different shape from that of modern humans, not bigger at all.

Not only that, but the structure and orientation of the sockets into which the thigh bones fit are distinctly different from those of modern humans. "We are left with little choice but to attribute these differences to locomotion and posture-related biomechanics," says Rak and B. Arensburg. For other observers, these differences make unlikely a close evolutionary relationship between Neanderthals and modern humans.

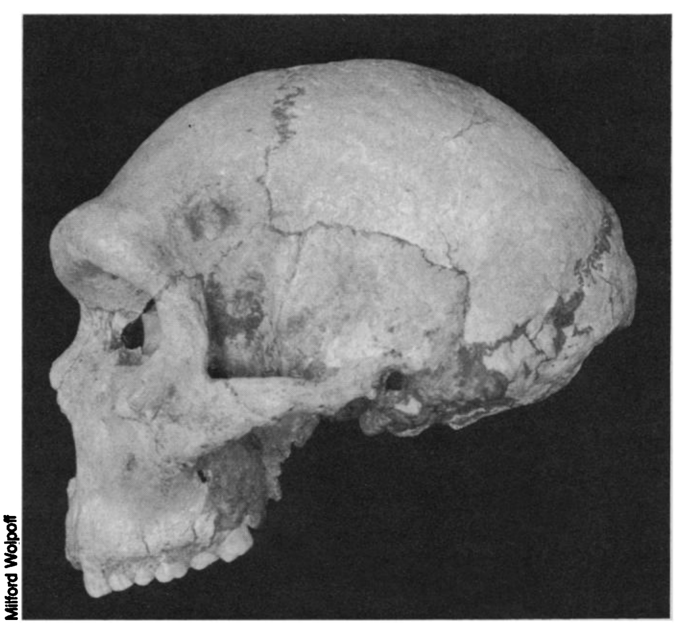
If the Kebara pelvis is not convincing evidence against an ancestor-descendant relationship between Neanderthals and modern humans, then a new result from a nearby cave surely is. The cave is Qafzeh, also in Israel, site of some early modern human cranial specimens that were discovered in the 1930s. What makes them interesting now is an age of 92,000 years produced by thermoluminescence dating: the new date doubles the previous estimate.

If the Qafzeh fossils really are this old—and biostratigraphic data and shortly-to-be-published electron spin resonance results suggest that they are—then there are several important implications. First, according to current fossil evidence, Neanderthals did not turn up in southwest Asia until about 60,000 years ago, which is more than 30,000 years later than the early modern humans at Qafzeh. The notion that Neanderthals evolved into modern humans therefore looks unlikely at best.

Second, taking Eurasia as a whole, Neanderthals and modern humans coexisted for at least 60,000 years, which not only reinforces the first point but also argues for a greater biological distinctiveness than is implied by the shared subspecific status.

A failure?

Believed by some to be an intermediate form between Homo erectus *and modern* Homo sapiens, *this 300,000 cranium from Greece belonged to a population that left no modern descendants, according to Stringer and Andrews.*



Third, in a more general sense, the status of early modern human cannot be recognized by cultural products, because the Qafzeh people, and other equivalent populations in Africa, are associated with tool technologies that have been labelled "more primitive" than Upper Paleolithic. "We are going to have to look for more subtle differences in the tool technologies, such as regional variation," says Alison Brooks of the Smithsonian Institution in Washington.

With a suggested age of 92,000 years, the Qafzeh fossils are about as old as the oldest early modern humans in Africa, those from Klasies River Mouth cave in South Africa. Does this mean that modern *Homo sapiens* might have evolved in southwest Asia, and not in sub-Saharan Africa as many researchers now favor? Without the recent genetic evidence, this certainly would be a tenable position. However, data on both nuclear and mitochondrial DNA point strongly to a sub-Saharan origin, as Stringer and Andrews outline in their review.

Given the genetic data and the ages of the Qafzeh and Klasies River Mouth fossils, the origin of modern *Homo sapiens* must be put at substantially earlier than 100,000 years. The split between sub-Saharan populations and the rest of the Old World presumably has occurred by Qafzeh times, with the cave standing right in the corridor to the rest of the Old World.

Why early modern human populations took 50 millennia to penetrate further into the Old World is something of a puzzle. Perhaps the environment was unfavorable? Perhaps the established Neanderthal populations impeded migration? Perhaps most likely of all is that early modern human fossils dating from before 40,000 years ago exist but remain to be discovered in Eurasia.

Stringer and Andrews finish their review with the warning that "paleoanthropologists who ignore the increasing wealth of genetic data on human population relationships will do so at their peril." They are alluding to the prolonged confrontation during the 1960s and 1970s between molecular biologists and paleoanthropologists over the likely date and identity of the first member of the human family. In that case the molecular evidence was much closer to the mark than was the fossil evidence. This time around the geneticists' contribution is being welcomed by a few, considered cautiously by many, and flatly rejected by almost no one. A distinct improvement. ■ ROGER LEWIN

ADDITIONAL READING

H. Valladas *et al.*, "Thermoluminescence dating of Mousterian 'Proto-Cro-Magnon' remains from Israel and the origin of modern man," *Nature (London)* **331**, 614 (1988).

Y. Rak and B. Arensburg, "Kebara 2 Neanderthal pelvis," *Am. J. Phys. Anthrop.* 73, 227 (1987).

Zeroing in on the Zeta Zeta Function

More evidence for the Riemann Hypothesis is provided by new method that speeds up the necessary calculations, also has applications to other large-scale computations

DAVID Hilbert—who in many ways set the course for 20th-century mathematics—was once asked what he would do if, as in the legend of Barbarossa, he found himself revived 500 years in the future. "I would ask," the great mathematician replied, "Has somebody proved the Riemann Hypothesis?"

The answer to Hilbert's question is still No, but mathematicians have amassed impressive amounts of numerical evidence in favor of the Riemann Hypothesis, which is a prediction about the mathematical behavior of a special function known as the Riemann zeta function. Recent work by Andrew Odlyzko at Bell Labs and Arnold Schönhage at the University of Tübingen has carried his numerical evidence to unprecedented levels, by means of algorithms that speedup the necessary calculations. Their techniques, moreover, have applications beyond the zeta function to other large-scale computations.

The Riemann zeta function has fascinated mathematicians for the past hundred years, ever since Bernhard Riemann showed that the properties of this complicated function have deep implications for the distribution of prime numbers—positive integers that are divisible only by themselves and 1—that is, 2, 3, 5, 7, 11, and so forth. In particular, Riemann established a program by which properties of the zeta function could be used to prove that the number of primes less than a given number x is approximately equal to x divided by the natural logarithm of x. The proof was completed some 30 years later, in the 1890s, independently by two French mathematicians Charles-Jean de la Vallée Poussin and Jacques Hadamard. The result is known as the Prime Number Theorem.

The Riemann Hypothesis is a prediction about the zeros of the zeta function—points where the function takes the value 0. Riemann showed that the zeta function—which was first studied by Leonhard Euler in the 18th century—could be defined for complex as well as real numbers. Complex numbers, which are obtained by adjoining the square root of minus one (a seemingly senseless, "imaginary" number) to the real line can be thought of as points in a plane. Riemann showed that the zeros of the zeta function (except for some "trivial" zeros that occur at the negative even integers) all lie within a thin strip of the complex plane—and this turns out to be enough to prove the Prime Number Theorem. The Riemann Hypothesis, however, goes much further: it asserts that these zeros lie exactly on the centerline of this strip.

One application is to check for bugs in computer operating systems and compilers.

If true, the Riemann Hypothesis has enormous implications for number theory. It would drastically improve the known estimates for the distribution of primes. (The Prime Number Theorem gives an *approximate* formula for the number of primes less than x; the *error* of this approximation is intimately related to the zeros of the zeta function.) Many other "theorems" in number theory are "conditioned" on the Riemann Hypothesis—that is, their proofs assume that the Riemann Hypothesis is true—and some other results are known to be equivalent to the Riemann Hypothesis. So there is no wonder why mathematicians keep looking at the zeta function.

The number and approximate location of zeros on any segment of the centerline can be determined by keeping track of sign changes of the zeta function—or more exactly, an adjusted version of the zeta function. (The zeta function can be adjusted so that it takes real values along the centerline; if it changes in sign from positive at one point to negative at another, then it must take the value 0 somewhere in between.) Another, more sophisticated technique makes it possible to count all the zeros within a rectangle (but does not specifically locate any of the zeros). If the rectangle