Neanderthals and modern humans--a key to understanding human evolution

Part 1

William Moore
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This is the first of a two-part article.

Two recent announcements of research into the relationship between Neanderthals and modern humans tend to add weight to the interpretation that the ancestors of these two human lineages parted genetic company quite a long time ago. Furthermore, these results support the view that human evolution has been characterized by numerous branches and many dead ends. If true, then modern humans, *Homo sapiens*, are the last survivors of a number of human forms that existed, and coexisted, at various times and places over at least the last 5 million years. Indeed, the current situation in which there is only one living human species may be the exception rather than the rule.

The first of these announcements, presented in the *Proceedings of the National Academy of Sciences* (Weaver, Roseman, and Stringer 2008), reports a study to estimate how much time would have been required for genetic drift (i.e., random changes in genetic material) to result in the observed differences in 37 cranial measurements made from Neanderthal and modern human specimens. The results place the split between the ancestors of modern humans and of Neanderthals at just over 500,000 years ago. Neanderthals first appear in the fossil record approximately 400,000 years ago. *Homo heidelbergensis*, a long extinct human species known from fossils dating to more than 500,000 years ago, is suggested as a possible common ancestor between Neanderthals and the lineage that ultimately gave rise to modern humans, and probably other, now extinct lineages as well. If there was indeed a genetic split (i.e., a speciation event) at more than 500,000 years ago, then Neanderthals are unlikely to have made any contribution to the modern human gene pool.

The second announcement reports the results of an analysis of mitochondrial DNA from a Neanderthal leg bone dating to 38,000 years ago found in a cave in Croatia (Sample, 8 August 2008, The *Guardian*). Mitochondrial DNA (mtDNA) is found only in the mitochondria, the ‘powerhouses' within cells, and is transmitted only from mothers to their offspring, as opposed to nuclear DNA, which is derived half from an individual's mother and half from its father. The study conducted at the Max-Planck Institute for Evolutionary Anthropology in Leipzig, Germany indicates that the mtDNA of Neanderthals is distinctly different from that of modern humans. Based on this analysis, the split between Neanderthals and the lineage that ultimately led to modern humans occurred approximately 660,000 years ago, a bit earlier but not out of line with the Weaver, Roseman, and Stringer estimate described above. The research also indicates that there appear to have been few changes in the Neanderthal mtDNA over time, leading to the interpretation that populations of that species may have been relatively small throughout its existence. A full sequencing of Neanderthal nuclear DNA is expected to be completed by the end of the year.

These and the results of other recent research have added new data to the controversy over the degree of relationship between modern humans and Neanderthals. Neanderthals were a form of humans that existed from approximately 400,000 years ago until about 38,000 years ago, spread across much of Europe and western Asia, based on the available fossil record. These are the stereotypical ‘cave men' of popular conception, with a variety of more or less distinctive physical traits such as a more massive bone structure, heavy brow ridges, and no (i.e., receding) chin. Neanderthal fossils were initially identified in the Neander Valley of Germany in 1856 and were seen as the first direct evidence that different kinds of humans had once existed, thus supporting the then new and controversial idea that humans had evolved from earlier forms.

Physically modern humans, on the other hand, first appear in the fossil record, in Africa, sometime between 100,000 and 200,000 years ago. They then spread, relatively rapidly, in geological terms, across the Eastern and Western Hemispheres, farther than any previous human form. The archaeological record associated with modern humans reveals a culture that was vastly richer than that of any previous human species. This includes not only a much more sophisticated technology, but also a wealth of artistic expression such as objects of personal adornment (i.e., jewelry) and representational art (e.g., the cave paintings of late Ice Age Europe). Clearly, the appearance of modern humans represents a true qualitative leap in human evolution.

In the century and a half since Neanderthal fossils were first discovered, scientific and popular opinion has fluctuated regarding just how different Neanderthals and modern humans really were. Some early portrayals of Neanderthals were skewed because they were based on the interpretation of a single, nearly complete skeleton of an elderly male who, due to arthritis, had a number of skeletal abnormalities. Later reconstructions of Neanderthal appearance, based on a larger number of specimens, have moderated the perceived differences with modern humans somewhat. Some researchers have even proposed that should a living Neanderthal be found (suitably dressed and groomed) walking the streets of a contemporary city no one would notice. This idea has been echoed in a recent series of auto insurance commercials in the US.

Research announcements over the last decade demonstrate how much the study of fossil DNA has become a part of paleontology and of the study of human evolution in particular, in addition to the more traditional analyses of fossil bone and other sources of data such as archaeology.

The development of this new source of data also serves to highlight the true nature of advances in scientific research, a process of conflict between interpretations of different kinds of data and differing theoretical perspectives. In this conflict, what at one time may appear to be solid interpretive constructs can be overthrown by new, more comprehensive syntheses that more effectively integrate existing and newly available data. This contentious process often reflects ‘outside' influences from political and social currents in the larger society.

In order to understand the significance of the new research findings it is necessary to review some basics in the study of human evolution and of Neanderthals in particular.

The two principal views of Neanderthals may be characterized as representing the ends of a range of interpretations between, on the one hand, full separation from modern humans at the species level and, on the other hand, differences with modern humans being barely more than the range of variation seen today between different populations of modern humans. The ‘very similar' end of the spectrum suggests that Europeans in particular have some genetic inheritance from the former Neanderthal population of that continent. At the other end of the spectrum is the interpretation that Neanderthals and the ancestors of modern humans parted company a very long time ago (i.e., more than 400,000 years ago) and that the genetic differences between the two amount to a separation at the species level. In other words, the two groups were genetically isolated and could not successfully interbreed. This difference in interpretation is expressed in taxonomic terms according to whether Neanderthals are classified as *Homo neanderthalensis,* a species within the genus *Homo* (i.e., man or human), but distinct from *Homo sapiens* (modern humans), or as *Homo sapiens neanderthalensis,* a subspecies equal in status to *Homo sapiens sapiens*, the subspecies designation representing modern humans.

Separation at the species level rests on whether gene flow can occur between distinct populations (see below). The question of whether or not Neanderthals and modern humans could interbreed has been touched on in popular culture, for example in such movies as *Clan of the Cave Bear* and *Quest for Fire*. These movies portray the time, in the latter portion of the last Pleistocene (Ice Age) glacial advance, when modern humans first appeared in Europe and the Middle East, beginning approximately 40,000 years ago, and apparently coexisted with Neanderthals for several thousand years before the latter seemingly disappear from the fossil record.

What was the nature of the interaction, if any, between these two populations? Did modern humans drive Neanderthals to extinction by being smarter and out-competing their more ‘primitive' relatives for food and other necessities or, perhaps, by outright, violent extermination? Or, did modern humans and Neanderthals interbreed, with the former being genetically swamped by the latter to a large degree? If this second interpretation is true then Neanderthals did not become extinct. Their seeming disappearance from the fossil record is because their descendants merged with and became largely indistinguishable from the modern human population.

There have been some attempts to interpret the former scenario (i.e., extinction of Neanderthals) as an indication of a basically violent human nature and, at the other extreme, to see the genetic merging of the two groups as representing a ‘hopeful' sign of a more peaceful human temperament (i.e., make love not war). The reality is likely to have been more complicated, and its unraveling will be highly instructive for understanding the course of human evolution as a whole. Both paleontological and genetic research over the last decade have provided much data relevant to addressing this question.

Over the course of the last half century, more or less since the discovery of the Australopithecine hominid fossils in East Africa, which confirmed that human ancestry stretches back millions of years, there have been two general views of human evolution--the unilineal on the one hand and the multilineal or branching view on the other. The term hominid refers to modern humans and all their ancestors and collateral relatives dating back to the split between hominids and the lineage that ultimately gave rise to chimpanzees, sometime between about 6.5 million and 10 million years ago. Human and chimpanzee DNA has about a 96 percent overlap, indicating a closer evolutionary relationship between these two groups than either has with other apes.

The unilineal view, also known as the single-species hypothesis, which was most widespread in the 1960s and 1970s, posits that the human mode of adaptation--characterized most particularly by (a) upright walking which frees the hands to carry objects and to make and use tools on a consistent basis, (b) increasingly complex forms of social organization, and (c) the capacity for abstract thought--was so different from those of all other animals that the normal patterns of biological evolution were substantially modified. In this view, pretty much from the start hominids adapted more by cultural means (i.e., learned behavior) than by evolutionary modification of their bodies, as other animals do. This permitted humans to expand into a wide variety of environments while continuing movement between geographically widespread populations, so that there was more or less constant genetic flow encompassing the entire species.

Continuing genetic unity among hominids meant, according to the unilinealist view, that speciation of isolated populations, the primary mechanism in biological evolution whereby new species split off from existing ones due to genetic differentiation, did not occur among human ancestors. While genetic divergence between geographically distant populations may have occurred, it never reached the point of reproductive isolation, due to the counteracting forces of culturally mediated adaptation and of culturally supported mobility and consequent gene flow.

Reproductive isolation means the inability of members of different species to create fertile offspring when mating with each other. For example, horses and donkeys can mate and produce mules, but mules cannot reproduce. Therefore, there is no gene flow between horses and donkeys. They are separate, but closely related species. The fact that members of these two species can mate and produce living, if reproductively sterile, offspring indicates that their respective genetic constitutions are quite similar and that their separation into distinct species occurred in the relatively recent past.

In the unilinealist interpretation, biological change in the human lineage occurred gradually and relatively uniformly across the entire geographic range that hominids inhabited. Advantageous genetic changes which may have arisen in one or another corner of the single, widely dispersed species were disseminated throughout the remainder of its range by matings between members of adjacent populations and/or migration followed by interbreeding with the local population. While hominid morphology (i.e., physical appearance) has changed over millions of years of evolution, this change is interpreted as having been gradual and progressive. Differences in skeletal form seen in hominid fossils of roughly contemporary age, interpreted by multilinealists as evidence of coexistence between different hominid species, are seen by the unilinealists as the result of marked sexual dimorphism (i.e., physical differences, such as size, between males and females) and/or populations with a high degree of genetic diversity.

The contrary school of thought, the multilineal or branching view, has held that although the human mode of adaptation is indeed different from those of other animals, its influence on hominid biological evolution has not been as great as is portrayed by the unilinealists, at least not until the emergence of modern humans. Multilinealists argue that throughout the overwhelming majority of the existence of hominids their populations were small, population density was low, and technological adaptation remained relatively simple and largely unchanged for very long periods of time. Therefore, gene flow was generally quite limited, especially across the vast distances populated by hominids (i.e., Africa and much of Eurasia), creating effective genetic isolation between remote populations. Furthermore, although hominids did have a unique adaptive niche (culture) it was not sufficient to create a substantial buffer against the selective pressures imposed by nature. Instead, multilinealists argue that hominids have undergone repeated speciation, with a variety of species adapting to particular environments and/or modes of survival. In some cases, different hominid species appear to have come together geographically and coexisted in close proximity, sometimes over millions of years (e.g., robust and gracile Australopithecines in eastern and southern Africa).

The multilinealist model of human evolution is in much closer accord with modern evolutionary theory. An example is Gould and Eldridge's theory of punctuated equilibrium in which a given species will tend to remain relatively unchanged except when an isolated population under unique selective pressure and/or random genetic drift becomes sufficiently different genetically so that its members can no longer successfully mate (i.e., produce fertile offspring) with members of the parent species. In other words, speciation occurs. In dialectical terms, the opposites of an isolated population's limited gene pool and the pressure of natural selection in a unique environment compounded by genetic drift reach a critical point that resolves in the emergence of a new species or extinction of that population.

Coming full circle, numerous research projects over several decades have been intended to address the question of whether Neanderthals and modern humans were members of the same or different species. The answer to this question will tend to support either the unilineal or multilineal view of human evolution and is, therefore, of great importance to our general understanding of human origins. However, despite these new research results, the available data at this time has not yet resulted in a clear resolution to this controversy.

To be continued