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Two Splits Between Human and Chimp Lines Suggested

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The split between the human and chimpanzee lineages, a pivotal event in human evolution, may have occurred millions of years later than fossil bones suggest, and the break may not have been as clean as humans might like.

A new comparison of the human and chimp genomes suggests that after the two lineages separated, they may have begun interbreeding.

The analysis, by David Reich, Nick Patterson and colleagues at the Broad Institute in Cambridge, Mass., sets up a serious conflict between the date of the split as indicated by fossil skulls, about 7 million years ago, and the much younger date implied by genetic analysis, as late as 5.4 million years ago.

The conflict can be resolved, Dr. Reich's team suggests in an article published in today's Nature, if there were in fact two splits between the human and chimp lineages, with the first being followed by interbreeding between the two populations and then a second split.

The suggestion of a hybridization has startled paleoanthropologists, who nonetheless are treating the new genetic data seriously. The earliest human-lineage fossil remains, like Sahelanthropus, seem clearly to have been bipeds, walking on two feet, but the ancestors of chimps presumably walked on their two feet and the knuckles of their hands, as do modern chimps.

"If the earliest hominids are bipedal, it's hard to think of them interbreeding with the knuckle-walking chimps -- it's not what we had in mind," said Daniel E. Lieberman, a biological anthropologist at Harvard.

Hybrid populations often go extinct because the males are sterile, Dr. Reich pointed out, so hybrid females may have mated with male chimps to produce viable offspring. The human lineage finally re-emerged from this hybrid population, Dr. Reich suggests, explaining the younger genetic dates, while the very early fossils with humanlike features may come from the earlier period before the hybridization.

David Page, a human geneticist at the Whitehead Institute in Cambridge, said the design of the new analysis was "really beautiful, with all the pieces of the puzzle laid out." Whether the hybridization will turn out to be the right solution to the puzzle remains to be seen, "but for the moment I can't think of a better explanation," he said.

These crucial events in early human evolution are hard to judge dispassionately, Dr. Page noted. "We'd like to have a more Victorian view of our genome," he said, "and this reminds us that we are really animals and gives us a glimpse of our past and of a story that we might like to have told in a different way."

Geneticists have previously made estimates of the human-chimp lineage split, chiefly by drawing up a primate family tree, based on the number of DNA differences in a small section of the genome, and then anchoring the tree to some well-attested date in the fossil record, like the split between orangutans and the other primates.

One such approach, in 2001, suggested the human and chimp lineages split somewhere between 4.6 and 6.2 million years ago, but recent discoveries of fossil skulls have pushed the likely date backward. The Sahelanthropus fossil, found in Chad in 2002, had upright gait, humanlike teeth and lived around seven million years ago.

The Reich team's study is a far more detailed analysis of the human and chimp genomes, and also draws on

DNA sequences from the gorilla, orangutan and macaque to iron out ambiguities. Overall, they calculate that the human and chimp lines must have split finally apart at the earliest 6.3 million years ago and more probably 5.4 million years ago, a sharp discrepancy with the Sahelanthropus date.

But besides averaging genome-wide differences in DNA to get on overall fix on when the two species split apart, they have also been able to scroll along the genome and estimate the relative age of each small section.

A principal finding is that the X chromosomes of humans and chimps appear to have diverged about 1.2 million years more recently than the other chromosomes. Females have two X chromosomes, males one X and one Y chromosome.

One explanation for this finding, Dr. Reich's team says, is that there was a hybridization between the recently separated chimp and human lineages. Although the genetics does not specify whether it was the chimp or human lineage that emerged from the hybrid population, Dr. Reich said he favored the idea that it was the human line.

The reason is that chimpanzee ancestors, well adapted for living off fruit in tropical forests, seem to have been adept at spinning off variations, such as gorillas who live on vegetation, and the human lineage, which exploited the drier woodlands that opened up between the forests.

Hybridization could have speeded adaptation to this challenging new environment and is something the emerging human lineage would have had more use for than the chimps in their stable environment, Dr. Reich said.

But the males in hybrid populations are often sterile. So the females may have had to mate with males in the chimpanzee lineage in order to produce viable descendants. In principle, they could have mated with males of the human lineage, but genetic evidence rules out that possibility, Dr. Reich said.

The Reich team's analysis is the first to have examined speciation in such a detailed way at the genomic level. Their suggestion that new species can form through a hybridization event is quite novel -- biologists have often assumed that hybrid populations would die out because of hybrid sterility.

David Pilbeam, a paleoanthropologist at Harvard, said the Reich team's report was one of the most interesting he had seen, but he found it unlikely that chimplike quadrupeds and early bipeds would have produced fertile offspring, given their different developmental programs.

Instead of invoking hybridization, Dr. Pilbeam suggested that another explanation might emerge for the very recent date implied by the genetic data for the human-chimp split. The genetic information itself gives relative ages, which are translated into real time by reference to a timescale established by early ape and monkey fossils.

If the splits implied by these fossils are in fact more ancient than currently believed, this might pull the genetic date far enough back to make the hybridization hypothesis unnecessary.

There has long been a tension between paleoanthropologists and geneticists, who look at human evolution from very different perspectives. But the conflicts have often had fruitful outcomes.

"The last 20 years has been a never ending collision between the molecular evolutionists and the interpreters of the fossil record," said Dr. Page, noting the latest was particularly sharp because of the hybridization idea. A specialist in the X and Y chromosomes, Dr. Page sounded not displeased with idea that the final divorce between chimps and humans should have centered on the X chromosome. "That was the last paragraph to be written in the separation agreement," he said.