PALEOANTHROPOLOGY

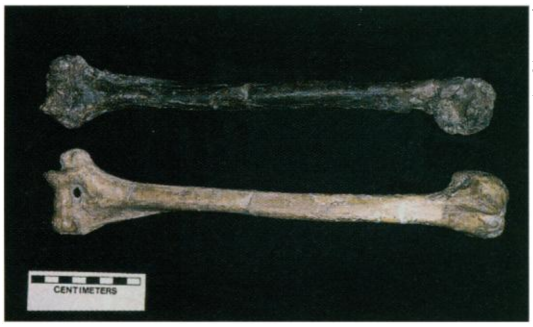
Did Neandertals Lose an Evolutionary "Arms" Race?

It has been called "The Mystery of Mount Carmel," a riddle embodied in the ancient humans who lived in caves around this Israeli mountain 40,000 to 100,000 years ago. They had a great deal in common: Not only were they in the same place at about the same time, but they hunted the same prey, used similar tools, and buried their dead in the same manner. What they didn't share, however, was their species: Some were short, stocky Neandertals, while others were tall, slender early modern humans. Only one group survived—and it wasn't the Neandertals. That, says University of New Mexico paleoanthropologist Erik Trinkaus, is the puzzle: "What is it about the early modern humans that made them ultimately evolutionarily successful?"

Now clues to that success are beginning to emerge, not from the stone tools, but from the bones of the toolmakers. By analyzing the shape and inner structure of fossil skeletons, Trinkaus and his colleagues can show how the bones were altered by behavior during an individual's lifetime. And Neandertal bones seem to reflect activity patterns that differed slightly from those of early moderns. At the Paleoanthropology Society meeting in April in New Orleans, Trinkaus and his colleagues reported that Neandertals' upper arm bones record more vigorous use, perhaps because they were less efficient at processing food than were early modern humans. And their hip bones indicate that Neandertals were more active as children, possibly because they had to follow along with the adults as the group hunted and foraged; early modern society, in contrast, might have been organized differently, allowing youngsters to stay safely in camp with baby-sitters. Both differences, says Trinkaus, might have given the evolutionary edge to modern humans.

The findings stand out amid the current ambiguity of the archaeological record in the Near East, says archaeologist John Speth of the University of Michigan: "This work is very worthwhile. There's an awful lot of behavior that is reflected in skeletal morphology. … We need more attempts like this to link morphology and anatomy with behavior." But, like many researchers, he also cautions that the leap from activity patterns to changes in group social structure is a stretch and needs further support.

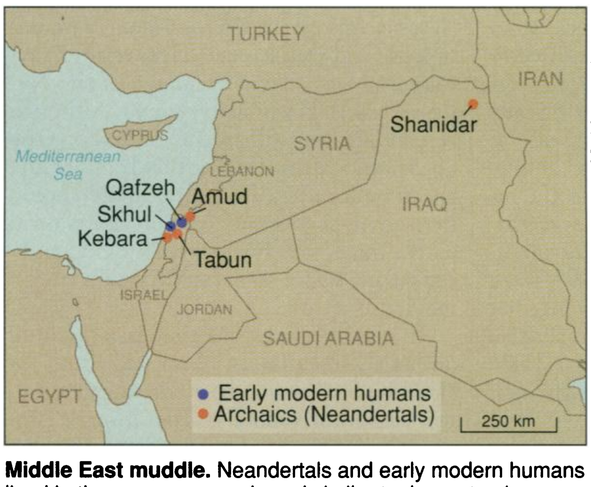
It isn't clear whether the two groups were using the sites around Mount Carmel at precisely the same time or alternately. But they left behind similar tool kits, which date to 80,000 and perhaps as early as 150,000 years ago for modern humans in caves at Qafzeh and Skhul, and 40,000 to 75,000 years ago (and perhaps more than 100,000 years ago) for Neandertals in caves at Tabun, Amud, Kebara, and, in Iraq, Shanidar. "Right now, there is nothing clear in the archaeology that indicates these humans differ in terms of behavior," says Harvard University archaeologist Ofer Bar-Yosef.



ERIK TRINKAUS

Early arms. Upper arm bones from early modern humans may record efficient foraging patterns that gave their owners an evolutionary edge.

That's why Trinkaus turned to the bones. "Some bones are developmentally plastic," he explains. This means, says Johns Hopkins University biological anthropologist Chris Ruff, who collaborates with Trinkaus, that "if you don't use it, you lose it. If you do use it, you gain more bone." In the racquet arms of professional tennis players, for example, the upper arm bone, or humerus, is 60% thicker than in the other arm. For those of us who don't compete at Wimbledon, the asymmetry between arms is closer to 5%.



SOURCE: O. BAR-YOSEF

Middle East muddle. Neandertals and early modern humans lived in the same area and used similar tools—yet only one group survived.

The best gauge of use, Trinkaus and Ruff have found, is a bone's internal architecture. "If you think of the shaft of a bone as a structural beam, like a hollow tube, you can measure the amount and distribution of bone in a cross section," says Trinkaus, and that indicates how much weight it bore and what kind of torsional or twisting forces it was subjected to on a regular basis. So the two scientists take x-rays—and computerized tomography scans, when possible—of fossil bones. They use software designed for orthopedic labs to calculate the area of the bone within each cross section. After factoring in the body shape and weight of the bone's owner—short, stocky Neandertals needed stronger leg bones to support their greater weight—Ruff can use mechanical engineering equations to figure out how much additional weight or force the bone could have sustained.

When Ruff and Trinkaus did this for major arm or leg bones from 17 Neandertals and early modern humans from the Middle East (and then added European specimens, for a total of 30), they were surprised. "I used to think there was a major difference in the strength of their legs," says Trinkaus, implying that Neandertals were ranging further afield in their foraging expeditions—a notion that had made its way into anthropology texts. "But if you take into account their body proportions, those differences in robusticity disappear." Other work, including recent experimental studies of animals by Daniel Lieberman of Rutgers University in New Jersey, supports this. He found that different-sized animals, when exercised equally on a treadmill, laid down proportionally similar amounts of new bone.

But if the foraging theory lost its legs, the bones did point to another area of divergence: the arms. "There was a major and highly significant difference in the strength of the upper arm," says Trinkaus. Working with Duke University paleoanthropologist Steven Churchill, he found that Neandertal humeri had much more bone than did moderns.

The implication, Churchill says, is that because the tool kits of the groups were similar, the moderns were probably more efficient at picking food that was easier to process, for example: "Reduced robusticity in the context of the same technology usually means they're working smarter."

The Neandertals may have pursued a wide range of foods, which required more work to consume, Churchill says. Lieberman has proposed that Neandertals relied more heavily on hunting for their food than on foraging because they may have used the environment in a different way—perhaps at different seasons or when it was colder than when the moderns were there. Or Neandertals may have been less efficient at using their tools to butcher or prepare their food: Work by Trinkaus and others has shown that their front teeth have more wear than do moderns' teeth, as if they needed to use them as vices to hold things.

This picture of inefficient Neandertals, says Trinkaus, fits with evidence from their hip joints. In studies published in 1993, Trinkaus examined a knob at the top of the femur, or thigh bone, which fits into the hip socket. At birth this knob, known as the femoral neck, is vertical like the shaft of the femur. But studies of modern humans have demonstrated that the more active the child, the more the femoral neck bends inward and downward as the youngster grows. And Trinkaus has found that the femoral necks of the Neandertals are more sharply bent than those of the early moderns, which indicates that the Neandertals were more active as children. Perhaps, he says, the Neandertals moved as a group in pursuit of their food, while the moderns could split up, leaving their young with baby-sitters while they hunted and bringing back food to them at the end of the day.

If Trinkaus is right, it would mean that a different way of life was emerging among the early moderns in the Skhul and Qafzeh caves. Better food procurement and a more elaborate social system that protected children to a greater degree could have produced changes in population health and survival that gave these people the means to evolutionary success. "It must be something else beyond the tools," Trinkaus says.

But while many of Trinkaus's colleagues do embrace his findings about arms and efficiency, some worry that going from hip structure to social structure is venturing too far. Bar-Yosef, for instance, grumbles that "I have my reservations about simplistic interpretations of the functional morphology. I see no evidence for different social structures."

Still, this summer Bar-Yosef and his colleague Mary Stiner of the University of Arizona plan to test Trinkaus's ideas about differences in behavior near Mount Carmel by looking for differences in the type of small animals that the two groups hunted or the cut marks that show how they butchered them: "We will try to test the hypothesis that they were using their arms differently. Minor differences can make a major difference in determining what population is more successful than another."

–Ann Gibbons

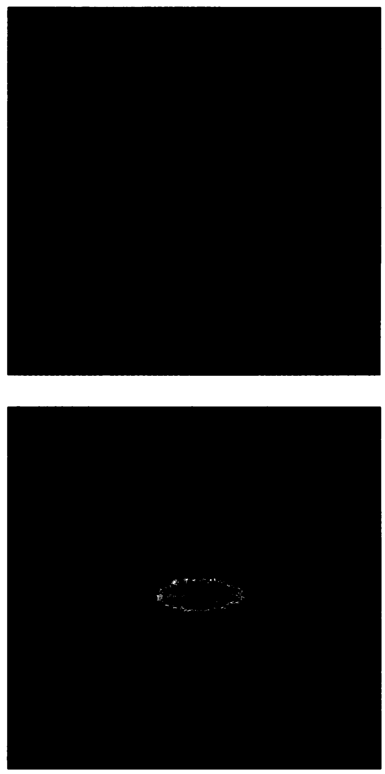
PHYSICS

Bose-Einstein Condensates Display Their First Tricks

A year ago this month, physicists finally realized what for decades had seemed at best a dream, if not a fantasy. On 5 June last year, a team at the University of Colorado and the National Institute of Standards and Technology (NIST) in Boulder created a new state of matter: a Bose-Einstein condensate, in which a cloud of atoms is cooled so close to absolute zero that their quantum-mechanical waves merge (*Science*, 14 July 1995, pp. 152, 182, and 198). In effect, the atoms act like a single macroscopic particle—one that still obeys the microscopic laws of quantum physics. But with barely 1000 atoms in a condensate that lasted just a few seconds, the Colorado team could do no more than say they'd done it.

Since that first triumphal announcement the field has erupted. It's gone from "a little bit of condensate squirting out of a tap and everyone cheering," says Oxford University physicist Keith Burnett, "to seeing these macroscopic condensates, millions of atoms, and the first quantitative experiments; the ability to directly photograph them, manipulate them, squeeze them, squash them, and even make them ring."

The progress was on display last month at a symposium on Bose condensates held in Ann Arbor, Michigan, by the American Physical Society Division of Atomic, Molecular, and Optical Physics. There, a team at the Massachusetts Institute of Technology (MIT) led by physicist Wolfgang Ketterle reported developing a new atom trap that can create condensates of 5 million sodium atoms, shaped like elfin cigars a third of a millimeter long, that survive for half a minute. With the new trap, along with a technique the MIT workers have developed for imaging condensates without destroying them, the MIT and Colorado groups are well on their way to studying this new state of matter. They may even be on the way to putting it to work in atomic lasers, which would do for atoms what lasers do for light and take the world of atomic manipulation and measurement to levels of precision and accuracy never before seen. "Before, the atom laser was just a pipe dream," says physicist William Phillips of NIST in Gaithersburg, Maryland, "but the existence of these Bose condensates makes it a reality."



MEWES ET AL.

Condensate unleashed. Successive images show shadow of a millimeter-long cloud of atoms containing Bose-Einstein condensate as it expands from its initial cigar shape *(top)*.

So far, however, only the MIT and Boulder teams are making this kind of headway. After the NIST–University of Colorado announcement last year, researchers speculated that any physicist might quickly concoct a Bose condensate with $50,000 in equipment and a little expertise. That seemed reasonable when reports of successful condensates followed from two other groups that had long been pursuing them, one led by Randy Hulet at Rice University and the other by Ketterle at MIT. But since then no one else has been able to create a cloud of atoms cold and dense enough to form a Bose condensate, and even Hulet says that it is only now that his group has compelling evidence for a condensate. "In the exuberance of the moment," says University of Colorado physicist Eric Cornell, "it was easy for us to forget that we'd been working at the project for 6 years before achieving it and there were lots of problems we had to solve along the way."

Indeed, most of the scientific progress came only this spring, after the MIT researchers redesigned the magnetic trap used to cool and hold the condensate. The first condensates were made by cooling atoms with lasers and confining them in a cone-shaped magnetic field that traps the coldest atoms at the center and allows hotter atoms to "evaporate" away. Because the cone-shaped field