The Cretaceous-Tertiary boundary. *This polished slab of the boundary interval from the Clear Creek North site 10 kilometers south of Trinidad, Colorado, includes the impact layer (3) where the peak of iridium abundance and shocked quartz grains are found. The iridium has also moved into the coal (4) above and the carbonaceous shale (1) below, but the shocked quartz has never been found beyond the impact layer. Layer 2 is a claybed.*

that Carter's features probably appear in contaminant grains picked up by ash flowing over the ground.

In light of this contrary evidence, Carter claims only that he has evidence of volcanic explosions generating shock pressures of 10 gigapascals or more, a claim that has yet to be accepted. That much shock is intense enough to produce shocked quartz of the sort found at the K-T, but he has found no example of it in volcanic ash. High volcanic temperatures probably make the quartz too plastic for it to record such shock levels, he says, except under rare circumstances theoretically predicted by Alan Rice of the University of Colorado. As yet no one has found a product of those circumstances.

If highly shocked quartz is found at the K-T boundary and at known impact sites but not in volcanic debris, the impact hypothesis would seem to be on solid ground. Officer, the leading spokesman for the volcano hypothesis, does not agree. He notes that Carter has found the same mineral features at and around the Gubbio, Italy, K-T boundary as he found at Toba. But Carter found no impact-shocked quartz at Gubbio. Therefore, Officer says, intense volcanism accompanied the K-T transition, and multiple sets of planar shock features are not always associated with the boundary.

Officer's implications aside, the burden of proof would seem to fall on the volcanic catastrophists. Carter's group is the only one of seven groups that has looked at the K-T boundary and not found quartz having multiple sets of lamellae. K-T shocked quartz has now been found in more than a dozen areas around the world at up to 12 sites in a single area. In fact, Bohor's group reports finding impact-type features at the K-T as close to Gubbio as in northern Italy. There have been no suggestions as to what would settle this contentious question, but one obvious possibility would be the cooperative collection and splitting of samples from volcanoes and a few of the best K-T sites.

Prime candidates for study might include the 20 K-T sites stretching from Alberta, Canada, to New Mexico that Izett and Bohor have compiled. These sites seem to have escaped much of the disturbance, alteration, and contamination that has helped fuel the impact-volcano controversy. In most cases the sediment layers include a carbonaceous shale at the bottom, a kaolinite bed, the K-T boundary impact bed, and a coal bed at the top. The 3- to 8-millimeter-thick impact bed always contains abundant shocked quartz, a peak in iridium, and the sudden increase in fern spores that marks the K-T boundary.

"There seems to be just one event there," says Izett. "I started off as a nonbeliever. What got me was the sudden appearance of these shocked minerals at the K-T. In the impact bed, you see grains everywhere that have these features in them. Just a millimeter or two below, you'll never see any of those features. That is staggering to me. The marine rocks [as at Gubbio] may not be the place to study the K-T. It may be in these quiet coal swamps." ■ RICHARD A. KERR

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The Origin of the Modern Human Mind

The early stages of human evolution have for a long time dominated discussions in paleoanthropology. A new hot topic is now emerging, however, and this focuses on the origin of modern humans, Homo sapiens. *Major questions relate to where the first modern human stock arose (Africa or the Near East?), how they came to populate, in the first instance, the Old World (by global evolution or by replacement?), and how big an evolutionary change was involved in the transition (revolution or continuous, gradual trajectory?). A recent meeting* in Cambridge, England—the third on the topic in a year—addressed these issues. Presented here is a sample of some of the issues relating to the properties of the modern human mind.*

The Human Psyche Was Forged by Competition

There is nothing in the known universe like the human psyche, says Richard Alexander of the University of Michigan, and the job of the biologist is to explain how it evolved. Taking a strictly Darwinian approach he argues that "the human psyche evolved as a vehicle serving the genetic or reproductive interests of its possessors." Specifically, these interests include survival through to reproductive age, the successful acquisition of mates, and a rewarding set of social interactions with both kin and nonkin.

Most higher primates live in groups and are highly social. Humans are the same, but even more so. There is a range of socioecological explanations for group-living in primates, and this includes efficient exploitation of resources and defense against predation. The exaggerated degree of sociality in humans demands a further explanation, suggests Alexander, and this is "group-against-group, within-species competition." This central driving force for human sociality leads to "balance-of-power races with positive feedback upon cooperative abilities and social complexity."

Alexander's hypothesis derives from a theme of Darwin's, namely the "Hostile forces of nature." Darwin had in mind those natural forces that make life difficult, such as predators, parasites, food shortages, and cli-

*"The origin and dispersal of modern humans," 22 to 26 March, Corpus Christi College, Cambridge, England.

mate. For humans, says Alexander, another "force" is added to the list: "The only plausible way to account for the striking departure of humans from their predecessors and all other species with respect to mental and social attributes is to assume that humans uniquely became their own principal hostile forces of nature."

The key engine in this evolutionary drive, suggests Alexander, is a positive feedback resulting from the close match between the competitors—human versus human—in the battle for survival. "In social-intellectual-physical competition, [members of the same species] are likely to be—as no other competitors or hostile forces can—inevitably no more than a step behind or ahead in any evolving system of strategies and capabilities. Evolutionary races are thus set in motion that have a severity and centrality as in no other circumstances." The result is a "runaway" evolutionary trajectory that is analogous to the mechanism favored by some biologists for the phenomenon of sexual selection that, among other things, produced exaggerated features such as the peacock's tail.

Alexander finds the hypothesis "immediately satisfying" because of its explanatory power. "It can explain any size or complexity of group; it accords with all of recorded human history; it is consistent with the fact that humans alone play competitively group-against-group on a large and complex scale; and it accords with the ecological dominance of the human species."

At the core of this evolutionary explanation is the idea that intense social interaction and manipulation demands unprecedented skills in dealing within one another. Human intelligence and human reflective consciousness are therefore seen as the product of natural selection for dealing with the most challenging things in the human environment: other humans, not, as has usually been assumed, technological exigencies. Alexander acknowledges Nicholas Humphrey of the University of Cambridge, as the progenitor of this aspect of his group-against-group hypothesis.

Why did intergroup competition become so important an evolutionary factor for early hominids as compared with other large primates? Citing the work of his Michigan colleague Richard Wrangham, Alexander suggests that at least part of this might have been because, unlike in most primates, in humans it is the females who at sexual maturity leave the group where they were born, to join a mate in another group. "Males become the bonding sex," says Alexander, "defending the home area as bands of relatives."

Interestingly, chimpanzees share this pattern of social structure, which leads Alexander to speculate that "if by some chance the human species should be extinguished while chimpanzees were not, there is a fair chance that chimpanzees would embark upon an evolutionary path paralleling in some important regards that taken by human ancestors across the past million years or so." Chimpanzees have remained chimpanzees, speculates Alexander, "by the predatory and competitive actions of humans." If, instead, chimps had been more human-like in their habits "they would have long ago suffered the same fate I believe had to befall the closer relatives of modern humans: extinction by their closest relatives, the evolving human line."

Seeking Hidden Messages in Stone Tool Technology

Stone tools are the stock-in-trade of prehistoric archeologists, because they give a tangible—albeit incomplete—record of subsistence activities of early hominids. Some researchers, however, look to stone artifacts for indications of less concrete elements of prehistory, such as language abilities in hominids earlier than *Homo sapiens*. Harold Dibble, an anthropologist at the University of Pennsylvania, did just this and concluded that certain criteria of shape and standardization of stone tools are in fact mute on the matter of the language abilities of the hominids that made them.

The argument that relates stone tools to language in the archeological records rests on the degree of arbitrary form that is imposed on the artifacts. In other words, the repeated imposition of arbitrary form implies that the toolmakers were capable of creating abstract rules in their lives that can be understood only in the context of a culture founded in a complex, spoken language.

Constraints in making stone tools. *Physical properties of starting material can impose patterns on tool kits.*

Dibble agrees, but warns that first you have to be certain that patterns of shape and size within and between stone tool assemblages are in fact arbitrary in the cultural sense. To test this he looked at variability in shape and dimensions of handaxes (or bifaces), scrapers, and flakes from Europe, the Near East, and Africa from sites that predate the appearance of *Homo sapiens*.

Stone handaxes, which classically are described as teardrop shaped, occur in the archeological record from 1.5 million years ago until around 100,000 years ago. Several researchers have examined the variability of handaxe architecture and have reported a high degree of standardization, with the length always being about 1.5 times greater than the width.

For Dibble, however, the striking apparent standardization in handaxe structure over long periods of time and great geographical distances suggests to him the very opposite of a constant mental template. The concept of arbitrariness, he says, "implies that we should see such patterns differ in different parts of the world and at different times, assuming that the cultural rules would vary from place to place."

However, it may be that the high degree of standardization is in fact more apparent than real, perhaps being the product of archeologists' classification. The strong correlation between length and width (1.5:1.0) that many researchers report is not surprising, says Dibble, given that "by definition, a biface is always longer than it is wide." The result is that "we are imposing limits to variability in the process of categorization," and it is this constrained variability that leads to the impression of standardization. Using a computer simulation Dibble showed how a continuous variation in dimensions for handaxes was categorized in the classic way when the classic handaxe definition was imposed on the data.

So-called scrapers are a major component of stone tool kits from 150,000 years ago until the beginning of the Upper Paleolithic in Europe, about 35,000 years ago. In fact, of the 63 types of stone artifact identified by the late French archeologist Francois Bordes, more than a third were said to be scrapers. Bordes categorized the 24 types of scrapers into four groups, according to general features, such as whether they had a single scraping edge, were double edged, and how the edges related to each other.

If each of the 24 different types of scraper is the product of preconceived design, says Dibble, "this patterning may reflect the presence of more-or-less modern cognitive, linguistic and/or cultural symbolic structures." Dibble believes, however, that "the typological variation among these tools instead reflects continuous reduction of the pieces through resharpening and remodification until their eventual discard." In some cases scrapers are retouched along just one edge, while in others both edges are worked. But in all cases the degree of reworking is limited by the size of the starting flake. "Reduction continued . . . until a particular minimum width was attained and the piece discarded," proposes Dibble.

The patterns of scrapers from archeological sites in France and the Near East are consistent with this model of scraper morphology, says Dibble, implying technological constraints, not mental templates, in the manufacture of scrapers. Therefore, he argues, "the [scraper] types recognized today cannot be used as evidence of native classification systems."

The last category of artifact that Dibble analyzed was flakes, and particularly Levallois flakes, which are struck from specially prepared cores. If the hominids who made Levallois flakes—between 150,000 and 35,000 years ago—had a particular form in mind when they were preparing the cores, then, argues Dibble, the flakes produced from the cores should be less variable in shape than flakes produced by other methods. An analysis of more than 8000 flakes from various sites in southern France showed that there was no significant difference in shape variability among Levallois flakes, retouched bifaces, and normal flakes.

Dibble's conclusion is conservative. "The primary conclusion is not that prehuman hominids did not talk," he says, "but rather than the kinds of evidence discussed here do not demonstrate that they did."

Refined Speech the Key to Being Thoroughly Modern?

More direct evidence of language capabilities comes from the anatomy of the modern human vocal tract, which, says Philip Lieberman of Brown University, is good for two things. The first is the production of a range of non-nasal vowel sounds that enhances the precision and rate of data transmission by speech. And the second is an increased likelihood of choking. Clearly, he says, the latter is the evolutionary price we paid for the former.

Because the human larynx—or more precisely, the supralaryngeal vocal tract—is apparently so committed to the single function of complex spoken language, the fossil record of this part of hominid anatomy should be a good indication of the parallel evolution of the neural mechanisms of language. Using this index, Lieberman sees the integrated anatomical and neural systems for speech having "evolved in some hominid lineages over the past 500,000 years." The final touch to the system—which enhanced vowel production and the danger of choking—occurred with the arrival of modern humans, he suggests, "some time within the past 100,000 years."

The overall construction of the human vocal equipment involves the enlargement of the vocal tract by a combination of dropping the larynx deeper into the neck and shifting the palate by flexing upward the base of the cranium. The architecture of the tongue, which, unlike the nonhuman primate tongue is rounded and extends into the pharynx, is crucial to fine manipulation of sounds. The ability to close off the airway to the lungs during swallowing, and the closing of the nasal passage in forming certain vowels allows for precision communication.

Some years ago Lieberman and his colleagues analyzed the vocal tract of Neanderthals, which predated and may have been displaced by modern humans, and found what they interpreted to be anatomical limitations in the range of speech sounds that could be produced. Specifically, the larynx is high in the neck, and the tongue is almost entirely within the mouth and does not form an important part of the wall of the pharynx. The result is that "the Neanderthal vocal tract inherently cannot produce vowels like [i] or [u]," concluded Lieberman. "Its output is also nasalized [which] would inherently be subject to higher phonetic errors."

This interpretation has been challenged by several workers who suggest that Neanderthals would have had command of a full range of speech sounds. "It is easy to demonstrate that this is impossible," says Lieberman, "and in doing so point out the key factors that differentiate the human supralaryngeal vocal tract and basicranium from that of archaic hominids." For instance, placing the rounded form of the modern human tongue into the elongated Neanderthal oral cavity effectively pushes the larynx below the level of the cervical vertebrae. "This reconstruction yields an impossible creature," says Lieberman. "No mammal has its larynx in its chest."

Citing the work of Jeffrey Laitman and his colleagues at Mount Sinai School of Medicine on the flexure of the cranial base, and his own work on vocal tract anatomy, Lieberman concludes that "The fossil record is not consistent with a sudden, coordinated restructuring of the basicranium and mandible to yield a modern human configuration." Adaptations to mouth breathing and different patterns of chewing probably provided some of the basic anatomy that is used in speech. But, he suggests, "the 'final' restructuring of the supralaryngeal vocal tract appears to have been driven by phonetic considerations." Many anthropologists see this "final" step as a key—perhaps *the* key—element in the emergence of *Homo sapiens*.

Body Ornaments Imply an Esthetic Revolution

The exuberantly painted caves and delicately carved personal objects at sites in southwestern France and northern Spain from 15,000 to 20,000 years ago are the epitome of the fluorescence of the modern human mind. Not surprisingly, prehistorians have by comparison frequently seen the beginning of the modern human period in Western Europe—the Upper Paleolithic—some 35,000 years ago as being relatively culturally impoverished, showing just the glimmerings of what was to appear later on.

In fact, argues Randall White of New York University, the transition from premodern humans to modern humans—from the Middle Paleolithic to the Upper Paleolithic—was much more abrupt than many researchers like to imagine. White has been studying body ornamentation—such as beads—and concludes that "it appears to have been complex conceptually, symbolically, technically and logistically right from the very beginning."

Several factors conspired to deemphasize expressions of human esthetics and symbolism in this early period—the Aurignacian—says White. One has been a concentration on material retrieved from burials, which in fact contain very few of the beads that are now thought to have been used for decorating clothing. Second, the great majority of the decorative beads have not been published. Many were recovered from sites during the early decades of this century and were then dispersed to collectors in this country, to remain mainly unstudied until very recently.

The amount of labor that clearly went into the production of these beads and other decorative items, the great distance over which raw material for the beads was often transported, and the distinct variability of styles between different sites speaks of keenly developed culture, argues White. The occurrence of body ornamentation—and all that is implied by it—is explosive, he says, and represents "one of the greatest explanatory challenges in all of hominid evolution."

■ Roger Lewin