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ANTHROPOLOGY: The Missing Years for Modern Humans

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trum. In the other mechanism, asymmetry in the distribution of material ("clumpy ejecta") above the electron-scattering photosphere unevenly screens the underlying light. Unlike global asphericity, this second mechanism is strongly dependent on wavelength, because only those spectral regions corresponding to line transitions of the chemical elements that make up optically thick clumps will be polarized.

From spectropolarimetry gathered on seven events, previous work in this young field has found SNe Ia to have low overall polarizations but occasionally strong line polarization features (*4*–*7*). The emerging picture is thus one of a globally spherical photosphere with clumpy (or otherwise asymmetrically distributed) ejecta overlying it. How can such studies shed light on the type Ia flame-propagation mystery? The latest models indicate that pure deflagrations leave behind lumpier ejecta than delayed detonations do (*3*, *8*).

Spotting trends in SNe Ia data has a long tradition of bearing rich fruit. In 1936, Walter Baade pointed out that the substantial homogeneity and extraordinary brightness of these objects could make them powerful cosmological tools. By the early 1990s, however, it became clear that the dispersion in peak intrinsic luminosity (by more than a factor of 10) complicated their use as "standard candles." The fix came in 1993, when Phillips (*9*) quantified a trend first noticed by Pskovskii (*10*) that intrinsically bright SNe Ia rise and decline in brightness more slowly than dim ones do. Various versions of the "light curve–width" relation have since provided the edifice upon which the entire SN Ia cosmology enterprise has been built, and served as touchstones for theoretical models of the explosions.

It is just such a trend that Wang *et al.* now identify in spectropolarimetry of 17 SNe Ia: Bright events show systematically weaker line polarization than dim ones do. This trend is consistent with the idea that different SNe Ia make the transition from deflagration to detonation at different times. The sooner it happens, the brighter the supernova and the more completely scoured the ejecta will be of the clumps left behind by the deflagration front. The agreement between model predictions and observations strengthens the case for a detonation phase.

Will all debate now end on the subject? It is doubtful. Critics will point out that the trend identified by Wang *et al*. specifically excludes all spectroscopically "peculiar" SNe Ia, which may constitute 30% or more of the total population (*11*). Fundamental advances often come from consideration of the differences seen in a sample, rather than from the similarities alone. And some are likely to withhold any judgment until full three-dimensional models capable of resolving the clumps and quantitatively tracking the resulting polarization become available. Simply put, too many mysteries still surround SNe Ia for anyone to grow complacent. An important clue appears to have been wrested from nature, but we are not ready to resolve the riddle of SNe Ia just yet.

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ANTHROPOLOGY

The Missing Years for Modern Humans

Fossil, archaelogical, and DNA evidence of three separate research teams provide insight into the period between the emergence of *Homo sapiens* in Africa and their appearance in Europe.

Ted Goebel

Current interpretations of the human fossil record indicate that fully modern humans emerged in sub-Saharan Africa by 195,000 years ago (*1*). By 35,000 years ago, modern humans thrived at opposite ends of Eurasia, from France to island southeast Asia and even Australia. How they colonized these and other drastically different environments during the intervening 160,000 years is one of the greatest untold stories in the history of humankind. Two reports on pages 226 and 223 of this issue (*2*, *3*) and one in a recent issue of *Science* (*4*) interpret some of the chapters of this story.

To understand the dispersal of modern humans, we must know when these populations expanded from Africa into Eurasia. For the past 20 years, many researchers in this field have been under the impression that this event could have occurred as early as 100,000 years ago (*5*), but new genetic evidence indicates that the spread out of Africa occurred much more recently, closer to 60,000 to 50,000 years ago (*6*).

However, independent corroborating evidence of this recent-dispersal hypothesis is required. Grine *et al.* (*2*) provide a first important test through the analysis of the modern human skull from Hofmeyer, South Africa. This skull was originally discovered in 1952, but it came from an eroded context and not an archaeological excavation and did not yield sufficient collagen for accurate radiocarbon dating. Using a combination of other dating techniques, Grine *et al.* show that sediment within the skull's endocranial cavity was deposited about 36,000 years ago.

Thus, here is the first skull of an adult modern human from sub-Saharan Africa that dates to the critical period, and one that can speak to the relationship of early moderns from Africa and Europe. The Hofmeyer skull is morphometrically more similar to modern humans of Upper Paleolithic Europe than to recent South Africans or Europeans, and it has little in common with Neandertals. Thus, 35,000 years ago, modern populations of sub-Saharan Africa and Europe shared a very recent common ancestor, one that likely expanded from east Africa 60,000 years ago (*7*) (see the figure). This population not only spread south into South Africa but also east into Eurasia, navigating across the Bab el-Mandab Strait of the Red Sea from the Horn of Africa to southern Arabia (*6*).

Archaeological evidence of the hypothesized passage across the Red Sea still eludes us, but the fossil and archaeological records for southeast Asia and Australia indicate that

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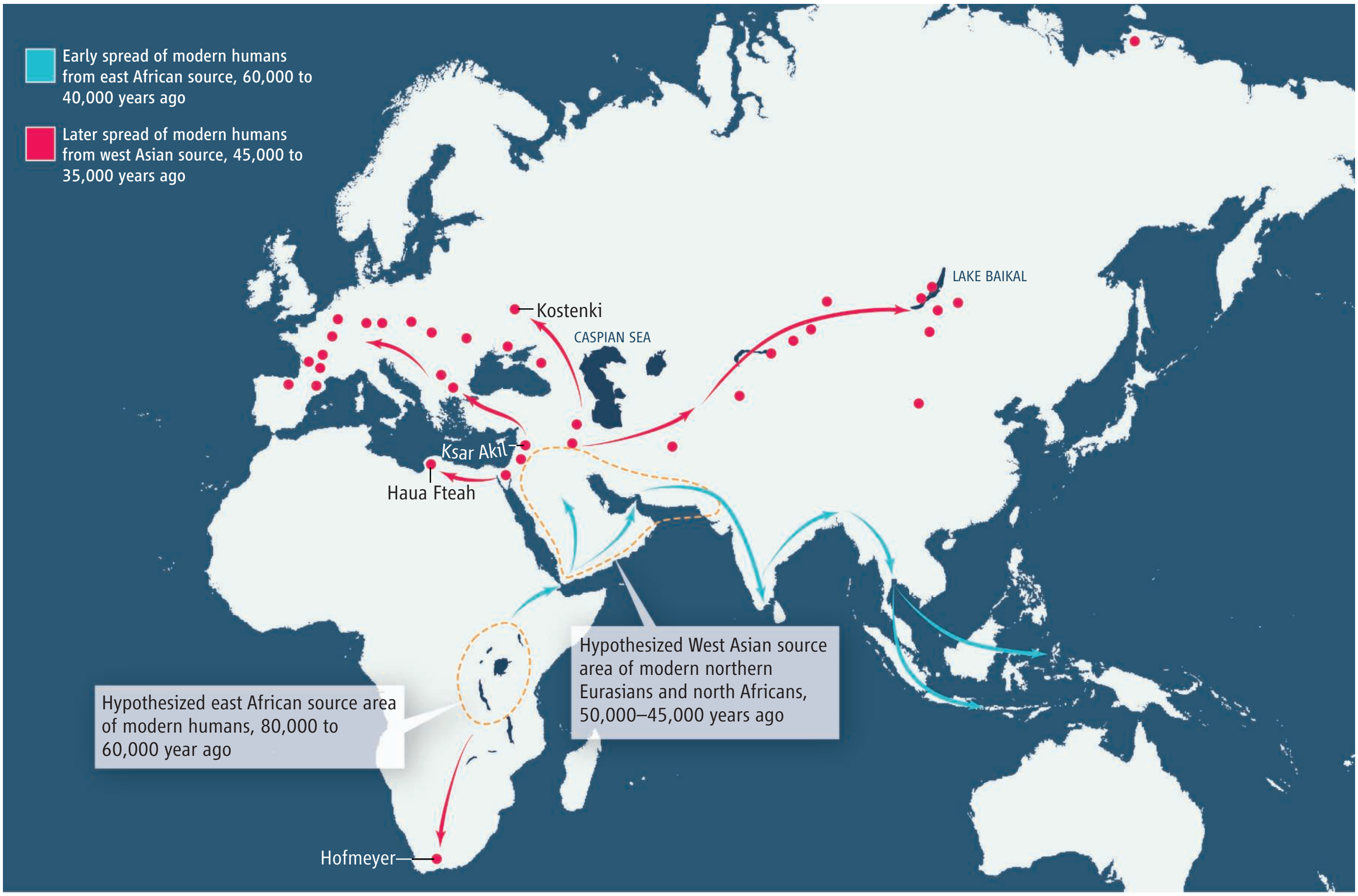

Human pathways. Reconstructed spread of modern humans during the late Pleistocene, and locations of some key early Upper Paleolithic archaeological sites. Grine *et al*., Olivieri *et al*., and Anikovich *et al.* provide new evidence confirming that early modern humans spread from southwestern Asia into northern Africa, Europe, and Russia about 45,000 to 40,000 years ago.

moderns had arrived in these regions by 50,000 years ago (*8*). The road east likely followed the south Asian coastal margin, a route requiring few modifications in adaptation other than those mandated by the initial exodus from Africa.

The spread north, however, required more time for adaptation to cope with colder temperatures, drier climates, and—most challenging of all—Neandertals. Despite these constraints, genetic records suggest that sets of genes, called haplotypes, carried by the first moderns into northern Eurasia existed by 45,000 years ago. Precisely where they evolved remains unknown; possibilities include southern Arabia, India, or other regions of interior western Asia (*6*, *9*). In any case, the outcome was a series of concomitant founding migrations about 40,000 years ago from western Asia to the Mediterranean, temperate Europe, Russia, and central Asia.

The best-known of these migrations is the move northwest into temperate Europe by modern humans (*10*, *11*), which led to Neandertal extinction after a short period of interaction (*12*–*15*). The other expansions out of western Asia presumed by the genetic evidence are not well understood. The reports by Olivieri *et al*. (*4*) and Anikovich *et al*. (*3*) provide important clues about them.

Olivieri *et al.* focus on mitochondrial DNA as a tool for researching modern human dispersal from western Asia. Their analysis suggests that two genetic lineages, the M1 and U6 haplogroups, originated simultaneously in western Asia between 45,000 and 40,000 years ago and from there spread with modern humans westward into northern Africa. The estimated timing of this event should not come as a surprise to archaeologists who interpret similarities in tool technologies and artifact forms as indicators of prehistoric population relationships. Through this “technocomplex” approach, they for years have theorized a historical link between the first Upper Paleolithic stone blade technologies in the Levant (called “Aurignacian” at sites like Ksar Akil, Lebanon) and similar blade technologies in northern Africa (called “Dabban” at sites like Haua Fteah, Libya) (*16*). Together the genetic and archaeological records indicate that the modern humans spread from the Levant into Mediterranean Africa by 40,000 years ago (*13*, *14*).

Another intriguing scene in the emerging story of modern humans is being played out at the famous Kostenki sites along the Don River, Russia, about 500 km south of Moscow. There, Anikovich, Sinitsyn, Hoffecker, and colleagues have unearthed archaeological evidence that the Upper Paleolithic—characterized by a series of new technologies and behaviors that are decidedly modern—had begun by 45,000 years ago. Because of perceived problems with the radiocarbon record of this time, they use optically stimulated luminescence techniques and precise chronostratigraphic correlations to define the age of the archaeological assemblages in question. The assemblages contain not just stone blades typical of the early Upper Paleolithic elsewhere in western Eurasia, but also some unique bone and ivory tools, perforated shell beads, and a carved chunk of ivory that may represent the head of an unfinished human figurine.

Although the early Kostenki assemblages are based on blade tools like those in other early Upper Paleolithic technocomplexes in Europe, this is where the similarities end and differences begin. First, the early Kostenki assemblages lack diagnostic artifacts of the Aurignacian, for example, split-based bone points, carinated end scrapers, and strangled blades. Second, they contain tool forms that are rare or absent in the typical Aurignacian, including dihedral burins, bifacial knives, and perforated fossil ornaments. As Anikovich *et al*. explain, the early Kostenki technocomplex is not Aurignacian; nor is it "transitional," reflecting a local shift from the Middle to Upper Paleolithic. Instead, it is something new and different: a fully developed Upper Paleolithic technocomplex with no European analog and no obvious root in the local Russian Middle Paleolithic. Although only human teeth not identifiable to species have been found associated with these early Kostenki assemblages, Anikovich *et al.* argue that they represent a pioneering group of moderns. If this is true, then the implications are clear: The first moderns to colonize European Russia may not have spread from the Levant via central Europe, but instead from interior western Asia via the Caucasus Mountains or from further east central Asia. This point of origin is consistent with the prediction by Olivieri *et al.* that modern Europeans developed out of several "regional enclaves" in greater western Asia.

So what we infer is this: Modern humans spread out of Africa very late in the Pleistocene—as recently as 60,000 to 50,000 years ago. One founding population spread east, reaching Australia by 50,000 to 45,000 years ago. Another remained in southwestern Asia or India, but after ~5000 to 10,000 years, its descendant populations dramatically expanded their range, colonizing lands as far removed from one another as northern Africa, temperate Europe, and the Russian Plain. They also reached southern Siberia by 45,000 years ago (*17*) and arctic Siberia by 30,000 years ago (*18*), but the retelling of these and other events in the missing years of modern human evolution must await new fossil and archaeological discoveries as well as continued DNA sampling of the world's living populations.

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PHYSICS

Electron Nematic Phase in a Transition Metal Oxide

Materials in which electrons interact strongly can exhibit unusual properties. Electrons have now been observed to assemble into a pattern like that seen in liquid crystals.

Eduardo Fradkin, Steven A. Kivelson, Vadim Oganesyan

Each time we encounter a new quantum state of matter, we learn more about the possible behavior of condensed matter systems. On page 214 of this issue, Borzi *et al.* (*1*) report their observation of an unusual metallic phase in ultrapure strontium ruthenate ($Sr_3Ru_2O_7$). Discovery of this state, known as a nematic phase, confirms earlier theoretical predictions and shows that electrons can assemble into some very exotic structures.

$Sr_3Ru_2O_7$ is a layered crystal with "tetragonal" symmetry, which means that it looks the same when rotated by 90°. Consequently, the electrical resistance should be the same in the x or y direction (if z is the rotation axis). Borzi *et al*. found that, for a limited range of magnetic fields and for temperatures below a critical temperature, this symmetry is spontaneously broken. That is, the resistivity in one direction becomes larger than the other by as much as a factor of 2. Spontaneous symmetry breaking is one of the defining features of phases of matter; for instance, although water is a uniform liquid, when cooled below its freezing temperature, it forms ice crystals with facets and even snowflakes with all sorts of beautiful spatial structures, which reflect the fact that at a molecular level, the atoms have spontaneously arranged themselves into a crystalline lattice. The symmetry breaking observed by Borzi *et al*. confirms the existence of the nematic phase.

In the conventional description of metals, the strongly interacting conduction electrons can be accurately represented as a gas of weakly interacting electron-like excitations, referred to as "quasiparticles." This description, known as Fermi liquid theory, works for many metallic systems. Under the right conditions, a Fermi liquid will transform into a low-temperature superconductor (in accord with the Bardeen-Cooper-Schrieffer theory) or, in some cases, into a charge- or spin-density wave. However, over the past two decades, new types of metallic materials with strongly correlated electrons have been discovered that do not fit this standard description. The list now includes the superconducting copper oxides, the colossal magnetoresistive manganites, and many other materials. Although Fermi liquid theory can account for some properties of these highly correlated materials, for broad ranges of temperature and composition this description fails utterly. Moreover, because of the strong interactions, a far broader spectrum of broken-symmetry phases might be possible. Indeed, several new quantum phases of matter have been discovered in the past 20 years, including "*d*-wave" superconductivity in the high-temperature superconductors and time-reversal symmetry-breaking superconductivity in Sr_2RuO_4 (a close relative of $Sr_3Ru_2O_7$) (*2*). The nematic metallic phase of $Sr_3Ru_2O_7$ discovered by Borzi *et al*. expands the list of new phases.

Fermi liquid behavior occurs where the Fermi energy (the quantum kinetic energy) of the electron fluid dominates the particle dynamics. In contrast, where the Coulomb interactions are dominant, electrons are known to form an insulating electron crystal. The electron fluids in strongly correlated metals lie in an intermediate range where neither of these energies is dominant. An analogy can be made with complex classical fluids, as shown in the top panel of the figure. There is generally a gas phase at high temperatures, where entropy

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