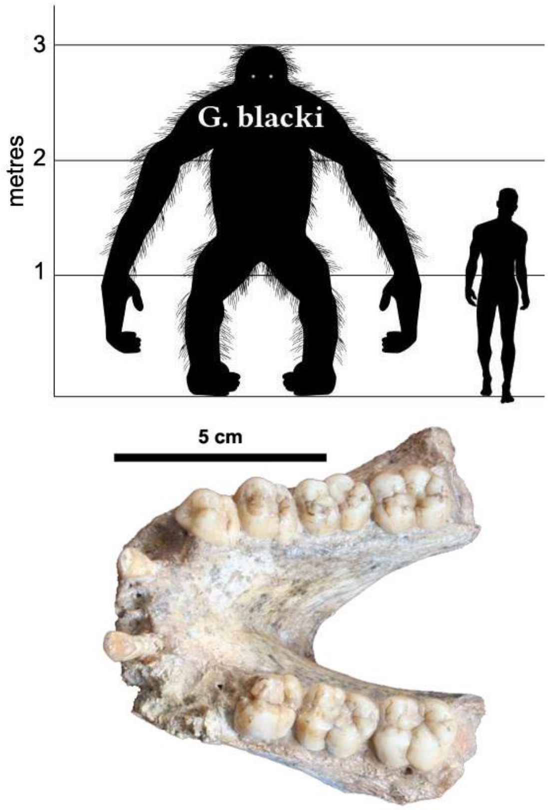
Why did the largest ever primate disappear?

PUBLISHED ON *January 17, 2024*

Chinese apothecary shops sell an assortment of fossils. They include shells of brachiopods that when ground up and dissolved in water allegedly treat rheumatism, skin diseases, and eye disorders. Traditional apothecaries also supply 'dragons' teeth', said by Dr Subhuti Dharmananda, Director of the Institute for Traditional Medicine in Portland, Oregon to treat epilepsy, madness, manic running about, binding qi ('vital spirit') below the heart, inability to catch one's breath, and various kinds of spasms, as well as making the body light, enabling one to communicate with the spirit light, and lengthening one's life. Presumably have done a roaring trade in 'dragons' teeth' since they were first mentioned in a Chinese pharmacopoeia (the *Shennong Bencao Jing*) from the First Century of the Common Era. In 1935 the anthropologist Gustav von Koenigswald came across two 'dragons' teeth' in a Hong Kong shop. They were unusually large molars and he realised they were from a primate, but far bigger (20 × 22 mm) than any from living or fossil monkeys, apes or humans.



Above: Size comparison of G. blacki with a 1.8 m tall human male; NB G.blacki probably walked on all fours, as do living orangutans when they rarely descend from the forest canopy. (Credit: Frido Welker) Below: Mandible of Gigantopithecus blacki from India (Credit: Prof. Wei Wang, Photo retouched by Theis Jensen)

Eventually, in 1952 (he had been interned by Japanese forces occupying Java), von Koenigswald formally described the teeth and others that he had found. Their affinities and size prompted him to call the former bearer the 'Huge Ape' (*Gigantopithecus*). By 1956 Chinese palaeontologists had tracked down the cave site in Guangxi province where the teeth had been sourced, and a local farmer soon unearthed a complete lower jawbone (mandible) that was indeed gigantic. More teeth and mandibles have since been found at several sites in Southern and Southeast Asia, with an age range from about 2.0 to 0.3 Ma. Anatomical differences between teeth and mandibles suggest that there may have been 4 different species. Using mandibles as a very rough guide to overall size it has been estimated that *Gigantopithecus* may have been up to 3 m tall weighing almost 600kg.

Plaque on some teeth contain evidence for fruit, tubers and roots, but not grasses, which suggest suggest that *Gigantopithecus* had a vegetarian diet based on forest plants. Mandibles also showed affinities with living and fossil orangutans (pongines). Analysis of proteins preserved in tooth enamel confirm this relationship (Welker, F. and 17 others 2019. Enamel proteome shows that *Gigantopithecus* was an early diverging pongine. *Nature*, v.**576**, p. 262–265; DOI: 10.1038/s41586-019-1728-8). It was one of the few members of the southeast Asian megafauna to go extinct at the genus level during the Pleistocene. Its close relative *Pongo* the orangutan survives as three species in Borneo and Sumatra. Detailed analysis of material from 22 southern Chinese caves that have yielded *Gigantopithecus* teeth has helped resolve that enigma (Zhang, Y. and 20 others 2024. The demise of the giant ape *Gigantopithecus blacki*. *Nature*, v. **625**; DOI: 10.1038/s41586-023-06900-0).

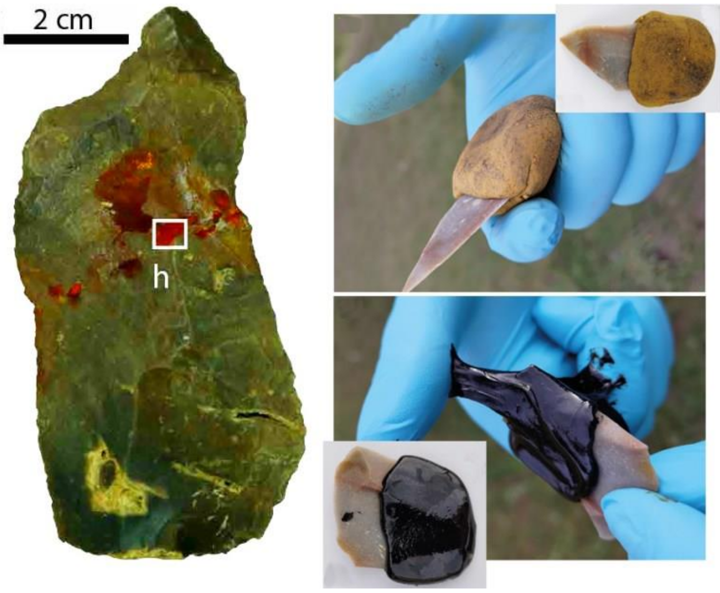
At the time *Gigantopithecus* first appeared in the geological record of China (~2.2 Ma), it ranged over much of south-western China. The early Pleistocene ecosystem there was one of diverse forests sufficiently productive to support large numbers of this enormous primate and also the much smaller orangutan *Pongo weidenreichi.* By 295 to 215 ka, the age of the last known *Gigantopithecus* fossils, its range had shrunk dramatically. The teeth show marked increases in size and complexity by this time, which suggests adaptation of diet to a changing ecosystem. That is confirmed by pollen analysis of cave sediments which reveal a dramatic decrease in forest cover and increases in fern and non-arboreal flora at the time of extinction. One physical sign of environmental stress suffered by individual late G. *blacki* is banding in their teeth defined by large fluctuations of barium and strontium concentrations relative to calcium. The bands suggest that each individual had to change its diet repeatedly over its lifetime. Closely related orangutans, on the other hand survived into the later Pleistocene of China, having adapted to the changed ecosystem, as did early humans in the area. It thus seems likely that *Gigantopithecus* was an extreme specialist as regards diet, and was unable to adapt to changes brought on by the climate becoming more seasonal. Today's orangutans in Indonesia face a similar plight, but that is because they have become restricted to forest 'islands' in the midst of vast areas of oil palm plantations. Their original range seems to have been much the same as that of *Gigantopithecus*, i.e. across south-eastern Asia, but *Pongo* seems to have gone extinct outside of Indonesia (by 57 ka in China) during the last global cooling and when forest cover became drastically restricted.

Neanderthals and the earliest 'plastic' handles

PUBLISHED ON *February 26, 2024*

February 2024 was a notable month for discoveries about ancient technology: first that of an ancient tool probably used in rope making and now signs of the use of a composite 'plastic' material in stone-tool hafts. Both are from Neanderthal sites in France, the first dated around 52 to 41 ka and the second in the Le Moustier rock shelters of the Dordogne – the type locality for the Mousterian culture associated with Neanderthals (Schmidt, P. *et al*. 2024. Ochre-based compound adhesives at the Mousterian type-site document complex cognition and high investment. *Science Advances*, v. **10**, article ead10822; DOI: 10.1126/sciadv.adl0822), dated at around 56 to 40 ka. The second discovery resulted from the first detailed analysis of unstudied artifacts unearthed from Le Moustier in 1907 by Swiss archaeologist Otto Hauser that had been tucked away in a Berlin Museum.

Patrick Schmidt of the University of Tubingen in Germany and colleagues from Germany, the US and Kazakhstan identified stone artifacts that show traces of red and yellow colorants. At first sight it could be suggested that they are decorations of some kind. However, they coat only parts of the stone flakes and are sharply distinct from the fresh rock surface and the sharpest edges. Another feature discovered during chemical analysis is that the colour is due to iron hydroxides (goethite) but this ochre is mixed with natural bitumen: the coating is a composite of an adhesive and filler not far different from what can be purchased in any hardware store.



LEFT: Stone flake from the Le Moustier site in France, partly coated with a reddish iron-rich colorant. RIGHT: Experimental stone flakes with 55:44 mix of goethite and bitumen (top) and pure bitumen (bottom) being handled. (Credit: Schmidt et al. Figs 1A, 3).

The authors tested the properties of the mixtures against those of bitumen alone – an adhesive known to have been used along with various tree resins to haft blades to spears in earlier times. In particular they examined the results of ‘cooking’ the substances. Whether unheated or ‘cooked’ a mixture of ochre and bitumen is up to three times stronger than pure bitumen. A further advantage is that the mixed ingredients are not sticky when cooked and cooled, whereas bitumen remains sticky, as the illustration clearly shows. Anyone who has handled a stone blade realises how sharp they are, and not just around the cutting edges. So Schmidt and colleagues tried to use the composite material as a protective handle when stone flake tools were gripped for cutting or carving. The composite handles worked well on scrapers and blades, even in the softer, ‘uncooked’ form

Similar composite adhesives are known from older sites in Africa associated with anatomically modern humans, but not for this particular, very practical use. It is perhaps possible that the use of bitumen mixed with ochre was brought into Europe by AMH migrants and adopted by Neanderthals who came into contact with them. Yet the limestones of the Dordogne valley yield both bitumen in liquid and solid forms, and ochers are easily found because of their striking colours. Long exposure of petroleum seeps drives off lighter petroleum compounds to leave solid residues that can be melted easily to tarry consistency. So there is every reason to believe that Neanderthals developed this technology unaided. As Schmidt has commented, “Compound adhesives are considered to be among the first expressions of the modern cognitive processes that are still active today”.

Earliest evidence for rope making: a sophisticated tool

PUBLISHED ON *February 7, 2024*

Even at my age, if I rummage through pockets of various bits of outdoor clothing there’s a good chance I’ll find a handy length of string that I have scavenged at some time. It’s a just-in-case thing, which I learned from my father and grandad. One can hardly imagine a hunter-gatherer not having string or lengths of sinew for that very reason. Cordage has many other uses than merely securing something: bags, mats, nets, snares, fabric, baskets, huts made of sticks and fronds, and even watercraft. Yet archaeological evidence for twine is exceedingly rare. The oldest known string – made of bark fibres – was found wrapped around a stone tool at a 52 to 41 ka Neanderthal site in the Rhône valley 120 km north-west of Marseille. Rope is somewhat more difficult to make as it requires twisting together several lengths of simpler cordage. Once that skill is cracked a rope maker is on the verge of engineering!

The reassembled rope-making tool from Hohle Fels Cave (Credit: Conard & Rots, Fig 2)

In 2015 archaeologists unearthed several pieces of worked mammoth ivory from the Hohle Fels Cave in SW Germany. They were dated to between 40 to 35 ka and associated with Aurignacian stone tools made by modern humans. Fifteen pieces could be fitted together to yield a 20 cm long ‘baton’. First believed to be some kind of ritual object, the fact that 4 circular holes had been bored through the ‘baton’ suggested it must have had some practical use, perhaps for straightening wooden shafts. Then it became clear that each hole was surrounded by spirals of carefully carved, V-shaped notches. Nicholas Conard and Veerle Rots of the University of Tubingen realised that the object may have been used for making rope using a technique known from the Egyptian pharaonic period into medieval times (Conard, N.J. & Rots, V. 2024. Rope making in the Aurignacian of Central Europe more than 35,000 years ago. *Science Advances*, v. **10**, article adh5217; DOI: 10.1126/sciadv.adh5217).

Frame from a movie showing how the tool may have been used to make ropes. The three 'feeders' twist foliage clockwise whereas the fourth pulls and imparts an anticlockwise twist to the three stands. (Credit: Conard & Rots, Supplementary material, Fig S15)

After a little practice, four people were able to make sturdy rope using a replica of the tool. Three twisted together fibrous materials, such as the stems and leaves of bulrushes (*Typha*), and pushed the rough cordage through the intact holes. A fourth person pulled the cordage through and counter-twisted the three strands into rope about 1.5 cm thick – thicker rope would also have required a tool with more holes and more operators. The spiral grooves maintained the initial clockwise rotation of each strand of cordage, so that when all three were twisted together in an anticlockwise sense the counter rotation held the rope together firmly. Remarkably, the small team were able to produce 5 m of rope in 10 minutes. Other common kinds of fibrous plant material, such as linden and willow were used successfully. Incidentally, the tool squeezed edible starch from the foliage of bulrushes. But it seems that this particular rope-making took only performed well for coarse materials. Making rope from finer firbres, such as animal sinew, nettle, flax and hemp would probably have required another design with smaller holes.

A movie of the manufacturing process can be downloaded.

How did African humans survive the 74 ka Toba volcanic supereruption?

PUBLISHED ON *March 25, 2024*

The largest volcanic eruption during the 2.5 million year evolution of the genius *Homo*, about 74 thousand years (ka) ago, formed a huge caldera in Sumatra, now filled by Lake Toba. A series of explosions lasting just 9 to 14 days was forceful enough to blast between 2,800 to 6,000 km^3 of rocky debris from the crust. An estimated 800 km^3 was in the form of fine volcanic ash that blanketed

South Asia to a depth of 15 cm. Thin ash layers containing shards of glass from Toba occur in marine sediments beneath the Indian Ocean, the Arabian and South China Seas. Some occur as far off as sediments on the floor of Lake Malawi in southern Africa. A 'spike' of sulfates is present at around 74 ka in a Greenland ice core too. Stratospheric fine dust and sulfate aerosols from Toba probably caused global cooling of up to 3.5 °C over a modelled 5 years following the eruption. To make matters worse, this severe 'volcanic winter' occurred during a climatic transition from warm to cold caused by changes in ocean circulation and falling atmospheric CO_2 concentration, known as a Dansgaard-Oeschger event.

There had been short-lived migrations of modern humans out of Africa into the Levant since about 185 ka. However, studies of the mitochondrial DNA (mtDNA) of living humans in Eurasia and Australasia suggest that permanent migration began about 60 ka ago. Another outcome of the mtDNA analysis is that the genetic diversity of living humans is surprisingly low. This suggests that human genetic diversity may have been sharply reduced globally roughly around the time of the Toba eruption. This implies a population bottleneck with the number of humans alive at the time to the order of a few tens of thousands (**see also**: Toba ash and calibrating the Pleistocene record; December 2012). Could such a major genetic 'pruning' have happened in Africa? Over six field seasons, a large team of geoscientists and archaeologists drawn from the USA, Ethiopia, China, France and South Africa have excavated a rich Palaeolithic site in the valley of the Shinfa River, a tributary of the Blue Nile in western Ethiopia. Microscopic studies of the sediments enclosing the site yielded glass shards whose chemistry closely matches those in Toba ash, thereby providing an extremely precise date for the human occupation of the site: during the Toba eruption itself (Kappelman, Y. and 63 others 2024. **Adaptive foraging behaviours in the Horn of Africa during Toba supereruption**. *Nature*, v. **627**; DOI: 10.1038/s41586-024-07208-3).

Selection of possible arrowheads from the Shinfa River site (Credit: Kappelman et al.; Blue Nile Survey Project)

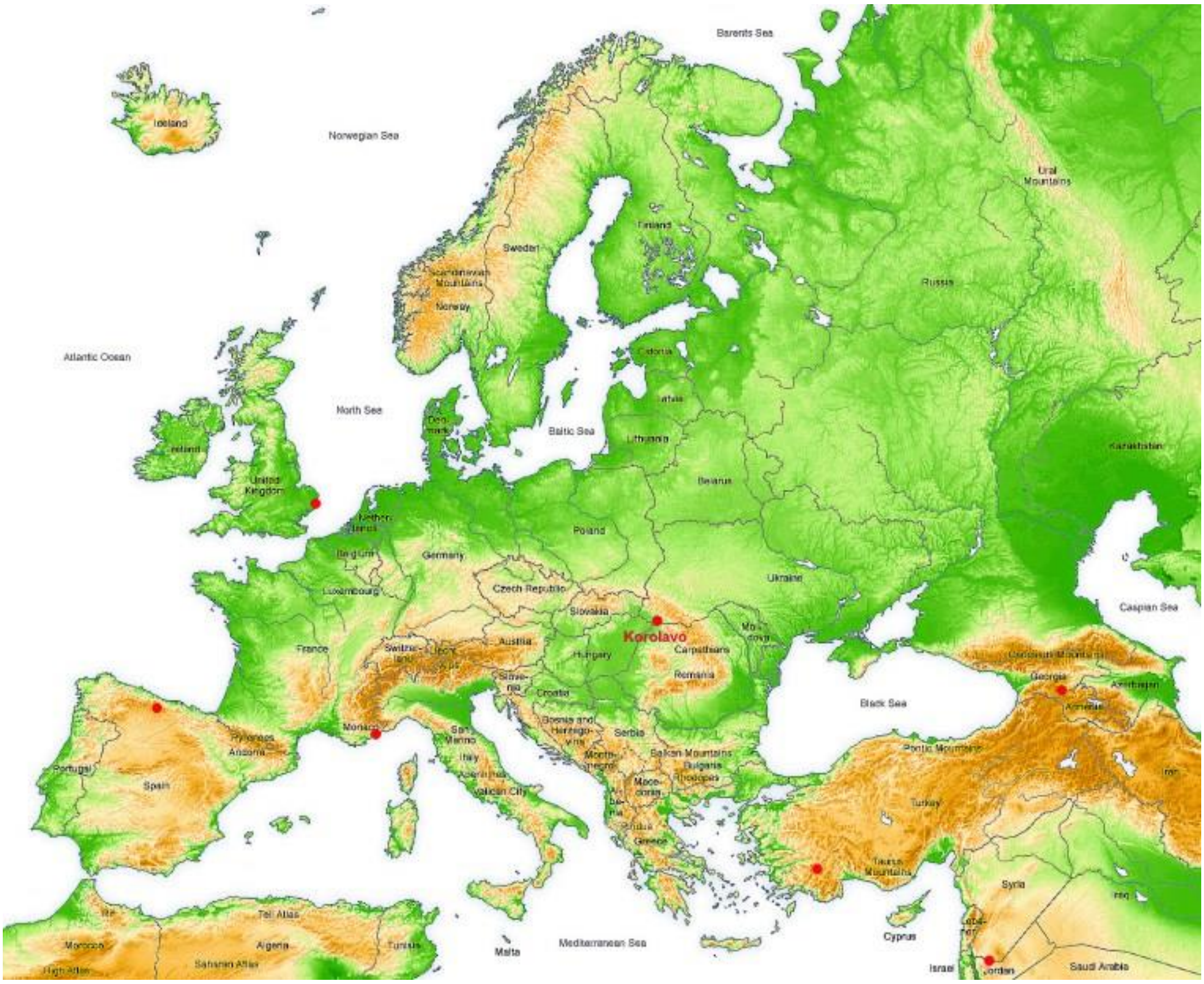
The artifacts and bones of what these modern humans ate suggest a remarkable scenario for how they lived. Stone tools are finely worked from local basalt lava, quartz and flint-like chalcedony found in cavities in lava flows. Many of them are small, sharp triangular points, some of which show features consistent with their use as projectile tips that fractured on impact; they may be arrowheads, indeed the earliest known. Bones found at the site are key pointers to their diet. They are from a wide variety of animal, roughly similar to those living in the area at present: from monkeys to giraffe, guinea fowl to ostrich, and even frogs. There are remains of many fish and freshwater molluscs. Although there are no traces of plant foods, clearly those people who loved through the distant effects of Toba were well fed. Although a period of global cooling may have increased aridity at tropical latitudes in Africa, the campers were able to devise efficient strategies to obtain victuals. During wet seasons they lived off terrestrial prey animals, and during the driest times ate fish from pools in the river valley. These are hardly conditions likely to devastate their numbers, and the people seem to have been technologically flexible. Similar observations were made at the Pinnacle Point site in far-off South Africa in 2018, where Toba ash is also present. Both sites refute any retardation of human cultural progress 74 ka ago. Rather the opposite: people may have been spurred to innovation, and the new strategies may have allowed them to migrate more efficiently, perhaps along seasonal drainages. In this case that would have led them or their descendants to the Nile and a direct route to Eurasia; along 'blue highway' corridors as Kappelman *et al*. suggest.

Yet the population bottleneck implied by mtDNA analyses is only vaguely dated: it may have been well before or well after Toba. Moreover, there is a 10 ka gap between Toba and the earliest accurately dated migrants who left Africa – the first Australians at about 65 ka. However, note that there is inconclusive evidence that modern humans may have occupied Sumatra by the time of the eruption. Much closer to the site of the eruption in southeast India, stone artifacts have been found below and above the 74 ka datum marked by the thick Toba Ash. Whether these were discarded by anatomically modern humans or earlier migrants such as *Homo erectus* remains unresolved. Either way, at that site there is no evidence for any mass die-off, even though conditions must have been pretty dreadful while the ash fell. But that probably only lasted for little more than a month. If the migrants did suffer very high losses to decrease the genetic diversity of the survivors, it seems just as likely to have been due to attrition on an extremely lengthy trek, with little likelihood of tangible evidence surviving. Alternatively, the out-of-Africa migrants may have been small in number and not fully representative of the genetic richness of the Africans who stayed put: a few tens of thousand migrants may not have been very diverse from the outset.

The first Europeans at the Ukraine-Hungary border

PUBLISHED ON *April 6, 2024*

Until this year, the earliest date recorded for the presence of humans in Europe came from the Sierra de Atapuerca in the Province of Burgos, northern Spain. The Sima del Elefante cave yielded a fossil mandible of a human dubbed *Homo antecessor* from which an age between 1.2 to 1.1 Ma was estimated from a combination of palaeomagnetism, cosmogenic nuclides and stratigraphy. Stone tools from the Vallonet Cave in southern France are around the same age. There is a time gap of about 200 ka before the next sign of human ventures into Europe, probably coinciding with an extreme ice age. They reappear in the form of stone tools and even footprints that they left between 1.0 to 0.78 Ma in ancient river sediments beneath the crumbling sea cliffs of Happisburgh in Norfolk, England. Although no human fossils were preserved, they too have been assigned to *H. antecessor*.



Topographic map of Europe (click to see full resolution in a new window). The Carpathian Mountains form an arc surrounding the Pannonian Basin (Hungarian Plains) just below centre. Korolevo and other Homo erectus and H. antecessor sites are marked by red spots (Credit: Wikipedia Commons)

In 1974 Soviet archaeologists discovered a site bearing stone tools by the River Tisza at Korolevo in the Carpathian Mountains close to the borders between Ukraine, Romania and Hungary. Korolevo lies at the northeastern edge of the Pannonian Basin that dominates modern Hungary. Whoever left the tools was on the westward route to a huge, fertile area whose game might support them and their descendants. The route along the Tisza leads to the River Danube and then to its headwaters far to the west. Going eastwards leads to the plains north of the Black Sea and eventually via Georgia to the Levant. On that route lies Dmanisi in Georgia, famous for the site where remains of the first hominins (*H. erectus,* dated at ~1.8 Ma) to leave Africa were found (see: Consider *Homo erectus* for what early humans achived). The tools from Korolevo are primitive, but have remained undated since 1974. 50 years on, Roman Garba of the Czech Academy of Sciences with colleagues from

Czechia, Ukraine, Germany, Australia, South Africa and Denmark have finally resolved their antiquity (Garba, R. and 12 others 2024. East-to-west human dispersal into Europe 1.4 million years ago. *Nature* v. **627**, p. 805–810; DOI: 10.1038/s41586-024-07151-3). Without fossils it is not possible to decide if the tool makers were *H. erectus* or *H. antecessor*.

The method used to date the site is based on radioactive ^{10}Be and ^{26}Al formed from oxygen and silicon in quartz grains by cosmic ray bombardment while the grains are at the surface. Since the half life of ^{26}Al (0.7 Ma) is less than that of ^{10}Be (1.4 Ma), after burial the $^{26}Al/^{10}Be$ ratio decreases and is a guide to the age of the sediment layer that contains the quartz grains. In this case the ag is quite precise (1.42 ± 0.28 Ma). The decreasing age of *H. erectus* or *H. antecessor* sites from the 1.8 Ma of Dmanisi in Georgia in the east, through 1.4 Ma (Korolevo) to 1.2 in Spain and France could mark the slow westward migration of the earliest Europeans. It is tempting to suggest possible routes as Garba *et al*. have. But such sparse and widely separated sites can yield very little certainty. Indeed, it is equally likely that each known site marks the destination of separate migrations at different times that ended in population collapse. The authors make an interesting point regarding the Korolevo population. They were there at a time when three successive interglacials were significantly warmer than the majority during the Early Pleistocene. Also glacial cycles then had ~41 ka time spans before the transition to 100 ka about 1 Ma ago. Unfortunately, no information about the ecosystem that the migrants exploited is available

See also: Prostak, S. 2024. 1.4-Million-Year-Old Stone Tools Found in Ukraine Document Earliest Hominin Occupation of Europe. *Sci News*, 7 March 2024. (includes map showing possible routes of early human dispersal)

Was the earliest human ancestor a European?

PUBLISHED ON *July 4, 2024*

Charles Darwin famously suggested that humans evolved from apes, and since great apes (chimpanzees, bonobos and gorillas) live in Africa he reckoned it was probably there that the human 'line' began. Indeed, the mitochondrial DNA of chimpanzees (*Pan troglodytes*) is the closest to that of living humans. Palaeoanthropology in Africa has established evolutionary steps during the Pleistocene (2.0 to 0.3 Ma) by early members of the genus *Homo*: *H. habilis*, *H. ergaster, H. erectus; H. heidelbergensis* and the earliest *H. sapiens*. Members of the last three migrated to Eurasia, beginning around 1.8 Ma with the individuals found at Dmanisi in Georgia. The earliest African hominins emerged through the Late Miocene (7.0 to 5.3 Ma): *Sahelanthropus tchadensi, Orrorin tugenensis* and *Ardipthecus kadabba*. Through the Pliocene (5.3 to 2.9 Ma) and earliest Pleistocene two very distinct hominin groups appeared: the 'gracile' australopithecines (*Ardipithecus ramidus; Australopithecus anamensis; Au. afarensis; Au. africanus; Au. sediba*) and the 'robust' paranthropoids (*Paranthropus aethiopicus*; *P. robustus* and *P. boisei*). The last of the paranthropoids cohabited East Africa with early *homo* species until around 1.4 Ma. Most of these species have been covered in Earth-logs and an excellent time line of most hominin and early human fossils is hosted by Wikipedia.

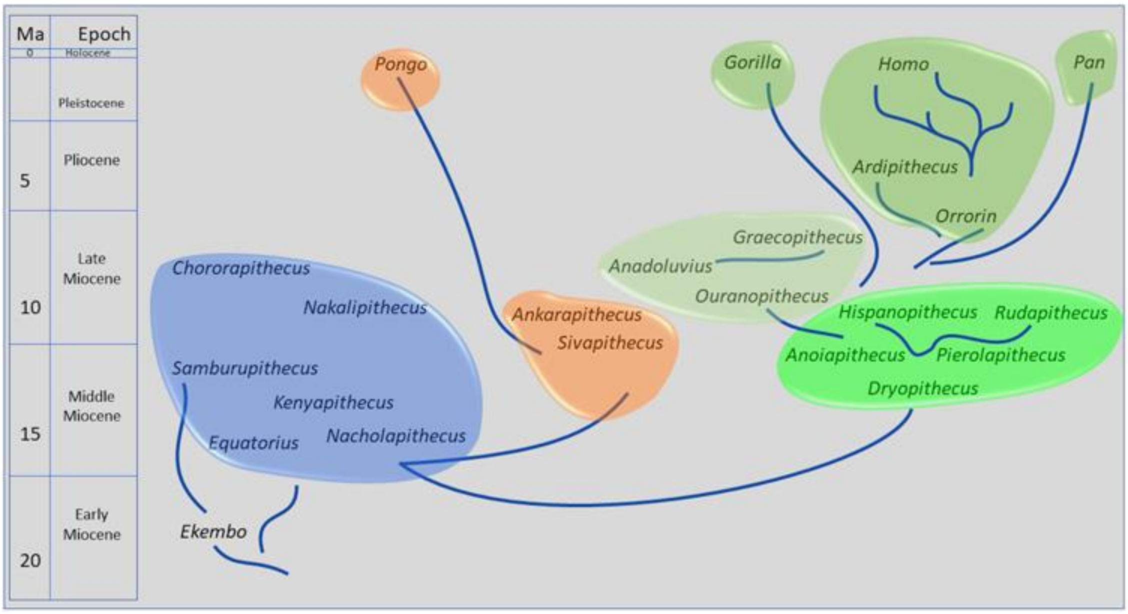
All apes, including ourselves, and fossil examples are members of the Family Hominidae (homin**id**s) which refers to the entire world. A Subfamily (Homininae) refers to African apes, with two Tribes.

One, the Gorillini, refers to the two living species of gorilla. The other is the Hominini (homin**in**s) that includes chimpanzees, living humans and all fossils believed to be on the evolutionary line to Homo. The Tribe Hominini is defined to have descended from the common ancestor of modern humans and chimps, and evolved only in Africa. As the definition of hominins stands, it excludes other possibilities! The Miocene of Africa before 7.2 Ma 'goes cold' as regards the evolution of hominins. There are, however fossils of other African apes in earlier Miocene strata (8 to 18 Ma) that have been assigned to the Family Hominidae, i.e. hominids, of which more later.

Much has been made of using a 'molecular clock' to hint at the length of time since the mtDNA of living humans and chimps began to diverge from their last common ancestor. That is a crude measure at it depends entirely on assuming a fixed rate at which genetic mutation in primates take place. Many factors render it highly uncertain, until ancient DNA is recovered from times before about 400 ka, if ever. The approach suggests a range from 7 to 10 Ma, yet the evolutionary history of chimps based on fossils is practically invisible: the earliest fossil of a member of genus *Pan* is from the Middle Pleistocene (1.2 to 0.8 Ma) of Kenya. Indeed, we have little if any clue about what such a common ancestor looked like or did. So the course of human evolution relies entirely on the fossil sequence of earlier African hominins and comparing their physical appearances. Each species in the African time line displays two distinctive features. All were bipedal and had small canine teeth. Modern chimps habitually use knuckle walking except when having to cross waterways. As with virtually all other primates, fossil or living, male chimps have large, threatening canines. In the absence of ancient DNA from fossils older than 0.4 Ma these two features present a practical if crude way of assessing to when and where the hominin time line leads.

In 2002 a Polish geologist on holiday at the beach at Trachilos on Crete discovered a trackway on a bedding plane in shallow-marine Miocene sediments. It had been left by what seems to have been a bipedal hominin. Subsequent research was able to date the footprints to about 6.05 Ma. Though younger than *Sahelanthropus*, the discovery potentially challenges the exclusivity of hominins to Africa. Unsurprisingly, publication of this tentative interpretation drew negative responses from some quarters. But the discovery helped resurrect the notion that Africa may have been colonised in the Miocene by hominins that had evolved in Europe. That had been hinted at by the 1872 excavation of *Oreopithecus bambolii* from an Upper Miocene (~7.6 Ma) lignite mine in Tuscany, Italy – a year after publication of Darwin's The Descent of Man.

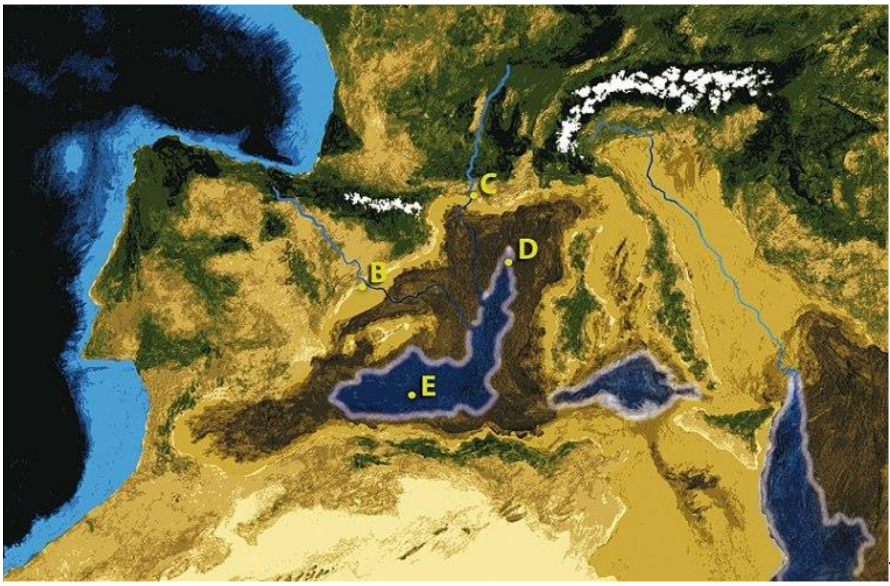
Lignites in Tuscany and Sardinia have since yielded many more specimens, so the species is well documented. *Oreopithecus* could walk on two legs, its hands were capable of a precision grip and it had relatively small canines. Its Wikipedia entry cautiously refers to it as 'hominid' – i.e. lumped with all apes to comply with current taxonomic theory (above). In 2019 another fascinating find was made in a clay pit in Bavaria, Germany. *Danuvius guggenmosi* lived 11.6 Ma ago and fossilised remains of its leg- and arm bones suggested that it could walk on two legs: it too may have been on the hominin line. But no remains of *Danuvius*'s skull or teeth have been found. There is now an embarrassment of riches as regards Miocene fossil apes from Europe and the Eastern Mediterranean (Sevim-Erol, A. and 8 others 2023. A new ape from Türkiye and the radiation of late Miocene hominines. *Nature Communications Biology*, v. **6**, article 842.; DOI: 10.1038/s42003-023-05210-5). A number of them closely resemble the earliest fossil hominins of Africa, but most predate the hominin record there by several million years.



Phylogenetic links between fossils assigned to Hominidae found in Africa and north of the Mediterranean Sea. (Credit: Sevim-Erol et al. 2023, Fig 5)

Ayla Sevim-Erol of Ankara University, Turkiye and colleagues from Turkiye, Canada and the Netherlands describe a newly identified Miocene genus, *Anadoluvius*, which they place in the Subfamily Homininae dated to around 8.7 Ma. Fragments of crania and partial male and female mandibles from Anatolia show that its canines were small and comparable with those of younger African hominins, such as *Ardipithecus* and *Australopithecus*. But limb bones are yet to be found. Around the size of a large male chimpanzee, *Anadoluvius* lived in an ecosystem remarkably like the grasslands and dry forests of modern East Africa, with early species of giraffes, wart hogs, rhinos, diverse antelopes, zebras, elephants, porcupines, hyenas and lion-like carnivores. Sevim-Erol *et al*. have attempted to trace back hominin evolution further than is possible with African fossils. They compare various skeletal features of different fossils and living genera to assess varying degrees of similarity between each genus, applied to 23 genera. These comprised 7 hominids from the African Miocene, 2 early African hominins (*Ardipithecus and Orrorin)* and 10 Miocene hominids from Europe and the Eastern Mediterranean. They also assessed similarities with 4 living genera, *Homo*, orang utan (*Pongo*), gorilla and chimp (*Pan*).

The resulting phylogeny shows close morphological links within a cluster (green 'pools' on diagram) of non-African hominids with the African hominins, gorillas, humans and chimps. There are less-close relations between that cluster and the earlier Miocene hominids of Africa (blue 'pool') and the possible phylogeny of orang utans (orange 'pool'). Sevim-Erol *et al*. note that African hominins are clearly more similar and perhaps more closely related to the fossils of Europe and the Eastern Mediterranean than they are to Miocene African hominids. This suggests that evolution among the non-African hominids ceased around the end of the Miocene Epoch north of the Mediterranean Sea. But it may have continued in Africa. Somehow, therefore, it became possible late in Miocene times for hominids to migrate from Europe to Africa. Yet the earlier, phylogenetically isolated African hominids seem to have 'crashed' at roughly the same time. Such a complex scenario cannot be supported by phylogenetic studies alone: it needs some kind of ecological impetus.



The western Mediterranean Basin at the end of the Miocene Epoch when the only water was in the deepest parts of the basin. (Credit: Wikipedia, Creative Commons)

Following a ‘mild’ tectonic collision between the African continent and the Iberian Peninsula during the late Miocene connection between the Atlantic Ocean and the Mediterranean Sea was blocked from 6.0 to 5.3 Ma. Except for its deepest parts, seawater in the Mediterranean evaporated away to leave thick salt deposits. Rivers, such as the Rhône, Danube, Dneiper and Nile, shed sediments into the exposed basin. For 700 ka the basin was a fertile, sub-sea level plain, connecting Europe and North Africa over and E-W distance of 3860 km. There was little to stop the faunas of Eurasia and Africa migrating and intermingling, at a critical period in the evolution of the Family Hominidae. One genus presented with the opportunity was quite possibly the last common ancestor of all the hominins and chimps. The migratory window vanished at the end of the Miocene when what became the Strait of Gibraltar opened at 5.3 to allow Atlantic water. This resulted in the stupendous Zanclean flood with a flow rate about 1,000 times that of the present-day Amazon River. An animation of these events is worth watching

A new timeline for modern humans’ colonisation of Europe

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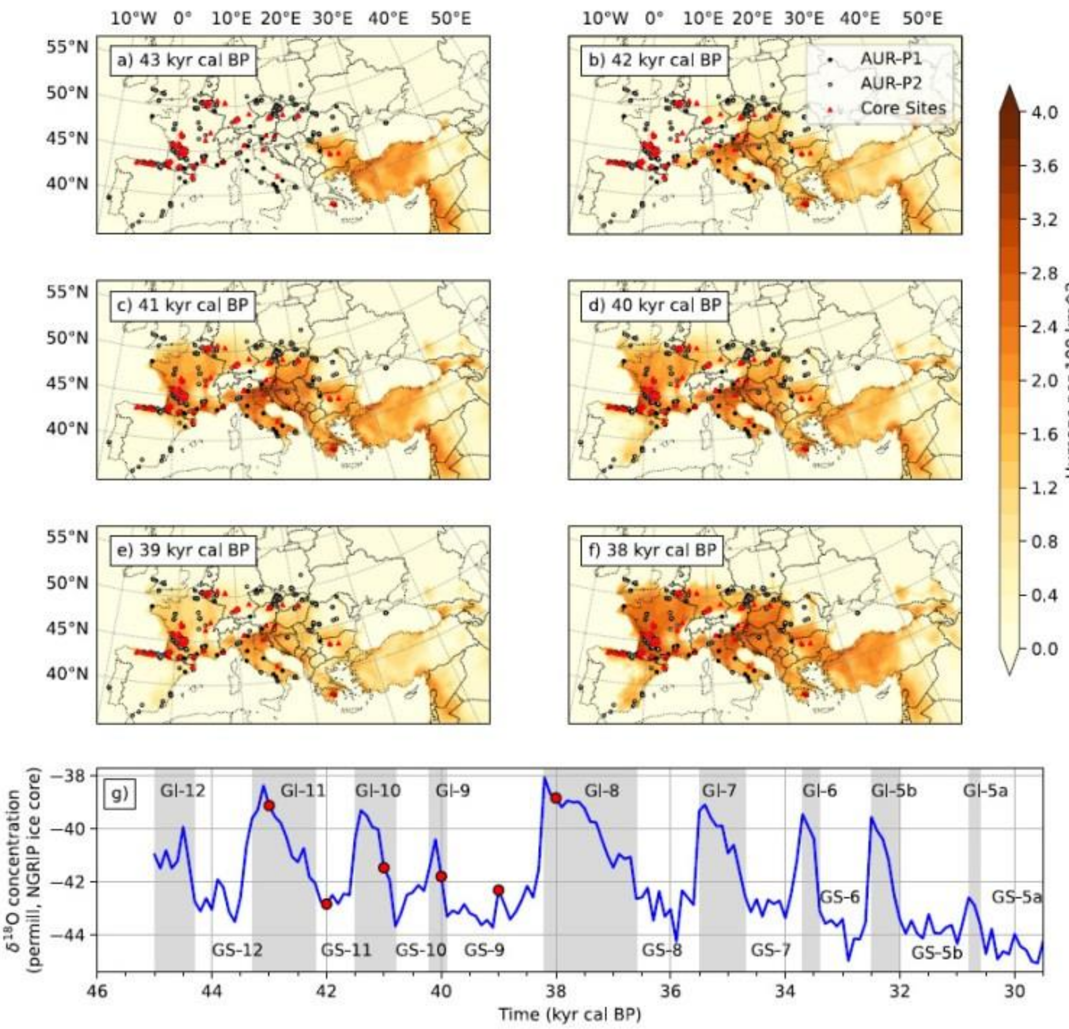
The earliest culture (or techno-complex) that can be related to anatomically modern humans (AMH) in Europe is called the Aurignacian. It includes works of art as well as tools made from stone, bone and antler. Perhaps the most famous are the ivory sculptures of ‘Lion-Man’ and Venus of the Hohlenstein-Stadel and Hohle Fels caves in Germany, and also the stunning cave art, of Chauvet Cave in France. Aurignacian artefacts that are dated at 43 to 26 ka occur at sites throughout Europe south of about 52°N. It was this group of people who interacted with the original Neanderthal population of Europe and finally replaced them completely. There is a long standing discussion over who ‘invented’ the stone tools, both human groups apparently having used similar styles of manufacture (Châtelperronian). Likewise, as regards the subsistence methods deployed by each; in one approach Neanderthals may have largely restricted their activities to roughly fixed ranges, whereas the incomers were generally seasonal nomads. As yet it has not been possible to show if the interbreeding between the two, which ancient and modern genetic data show, preceded the Aurignacian influx or continued when the met in Europe. Whatever, Neanderthals as a distinct human group had disappeared from the geological record by 40 ka. (Note that the three thousand years of coexistence is as long as the time between now and the end of the Bronze Age, about 150 generations at least.) But that aspect of European human development is not the only bone of contention about the spread into Europe. How did the Aurignacian people fare during and after their entry into Europe?

'Lion-Man' and 'Venus' from caves at Hohlenstein-Stadel and Hohle Fels in Germany.

Despite continuing discovery of AMH sites in Europe, and reappraisal of long-known ones, there are limits to how much locations, dates, bones and artifacts can tell us. The actual Aurignacian dispersal of people across Europe is confounded by the limited number of proven occupation sites. These were people who, like most hunter gatherers, must have moved continually in response to variations in the supply of resources that depend on changing climatic conditions. They probably travelled 'light', occupied many temporary camp sites but few places to which they returned generation after generation. Temporary 'stopping places' are difficult to find, showing little more than evidence of fire and a 'litter' of shards from retouched stone tools (debitage), together with discarded bones that show marks left by butchery. A group of archaeologists and climate specialists from the University of Cologne, Germany have tried to shed some light on the completely 'invisible' aspects of Aurignacian dispersal and subsistence using what they have called – perhaps a tribute to Frank Sinatra! – the 'Our Way Model' (Shao, Y. *et al.* 2024. Reconstruction of human dispersal during Aurignacian on pan-European scale. *Nature Communications*, v. **15**, Article 7406; DOI: 10.1038/s41467-024-51349-y. Click link to download a PDF).

The reality of hunter-gatherer life during a period of repeated rapid change in climate would clearly have been complex and sometimes precarious. To grasp it also needs to take account of human population dynamics as well as climatic and ecological drivers. The team's basic strategy was to combine climate and archaeological data to model the degree to which human numbers may have fluctuated and the extent and direction of their migration. Three broad factors would have driven both: environmental change; culture – social change, curiosity, technology; and human biology. Really, environmental change is the only one that can be addressed with any degree of precision through records of climate change, such as Greenland ice cores. Archaeological data from known sites should provide some evidence for technological change, but only for two definite phases in Aurignacian culture (43-38 ka and 38-32 ka). Dating of Aurignacian sites establishes some time calibration for episodes of occupation, abandonment and resettlement. Issues of human biology can be addressed to some extent from ancient genetics, where suitable bones are available. However, the 'Our Way Model' is driven by climate modelling and archaeology. It outputs an historical estimate of 'human existence potential' (HEP) that includes predictions of carbon storage in plants and animals – i.e. potential food resources – expressed as regional population density in Europe. The technical details are complex, but Shao *et al.*'s conclusions are quite striking.



Maps of estimated anatomically modern human population density during the first six thousand years of Aurignacian migration and palaeoclimate record from the Greenland NGRIP ice core, with shaded warm episodes – red spots indicate the time of the population estimates above. (Credit: Shao et al. Fig. 1)

Climate change in the later stages of cooling towards the last glacial maximum at ~20 ka was cyclical, with ten Dansgaard-Oeschger cold stadial events capable of 'knocking back' both population density and the extent of settlement. In the first two millennia expansion from the Levant into the Balkans was slow. From 43 to 41 ka the pace quickened, taking the Aurignacian culture into Western Europe, with an estimate total European AMH population of perhaps 60 thousand. A third phase (41 to 39 ka) shrank the areas and densities of population during a prolonged cold period. The authors suggest that survival was in Alpine refuge areas that AMH people had occupied previously. Starting at around 38 ka, a lengthy climatic warm period allowed the culture to spread to its maximum extent reaching southern Britain and the north and east of the Iberian Peninsula. Perhaps by then the AMH population had evolved better strategies to adapt to increasing frigid conditions. But by that time the Neanderthals had disappeared from Europe freeing up territory and food resources. That too may have contributed to the expansion and the sustenance of an AMH total population of between 80 and 100 thousand during the second phase of the Aurignacian.

It's as well to remember that this work is based on a model, albeit sophisticated, based on currently known data. Palaeoanthropology is extremely prone to surprises as field- and lab work progresses …

See also: New population model identifies phases of human dispersal across Europe. *EurekaAlert*, 4 September 2024; Kambani, K. 2024. The Dynamics of Early Human Dispersal Across Europe: A New Population Model. *Anthropology.net*, 4 September 2024.

Hominin footprints in Kenya confirm two species occupied the same ecosystem the same time

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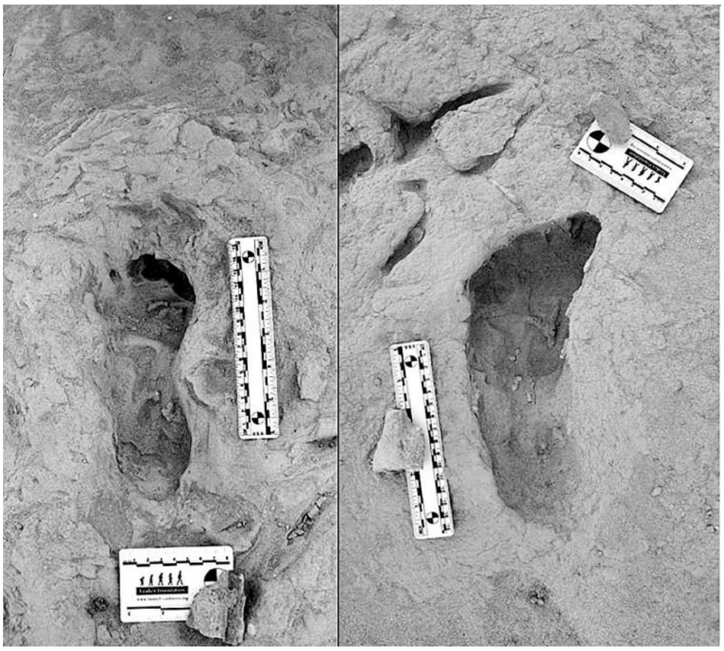

1.5 Ma old footprints from Koobi Fora, Kenya: left – right foot of H. erectus; right – left foot of Paranthropus boisei. Credit: Kevin Hatala. Chatham University

For the last forty thousand years anatomically modern humans have been the only primates living on Planet Earth with a sophisticated culture; i.e. using tools, fire, language, art etcetera. Since *Homo sapiens* emerged some 300 ka ago, they joined at least two other groups of humans – Neanderthals and Denisovans – and not only shared Eurasia with them, but interbred as well. In fact no hominin group has been truly alone since Pliocene times, which began 5.3 Ma ago. Sometimes up to half a dozen species occupied the habitable areas of Africa. Yet we can never be sure whether or not they bumped into one another. Dates for fossils are generally imprecise; give or take a few thousand years. The evidence is merely that sedimentary strata of roughly the same age in various places have yielded fossils of several hominins, but that co-occupation has never been proved in a single stratum in the same place: until now.

The Koobi Fora area near modern Lake Turkana has been an important, go-to site, courtesy of the Leakey palaeoanthropology dynasty (Louis and Mary, their son and daughter-in-law Richard and Meave, and granddaughter Louise). They discovered five hominin species there dating from 4.2 to 1.4 Ma. So there was a chance that this rich area might prove that two of the species were close neighbours in both space and time. In 2021 Kenyan members of the Turkana Basin Institute based in Nairobi spotted a trackway of human footprints on a bedding surface of sediments that had been deposited about 1.5 Ma ago. Reminiscent of the famous, 2 million years older Laetoli trackway of *Australopithecus afarensis* in Tanzania, that at Koobi Fora is scientifically just as exciting for it shows footprints of two hominin species *Homo erectus* and *Paranthropus boisei* who had walked through wet mud a few centimetres below the surface of Lake Turkana's ancient predecessor (Hatala, K.G. and 13 others, 2024. Footprint evidence for locomotive diversity and shared habitats among early Pleistocene hominins. *Science*, v. **386**, p. 1004-1010; DOI: 10.1126/science.ado5275). The trackway is littered with the footprints of large birds and contains evidence of zebra.

One set of prints attributed to *H. erectus* suggest the heels struck the surface first, then the feet rolled forwards before pushing off with the soles: little different from our own, unshod footprints in mud. They are attributed to *H. erectus*. The others also show a bipedal gait, but different locomotion. The feet that made them were significantly flatter than ours and had a big toe angled away from the smaller toes. They are so different that no close human relative could have made them. The local fossil record includes paranthropoids (*Paranthropus boisei*), whose fossil foot bones suggest an individual of that speciesmade those prints. It also turns out that a similar, dual walkers' pattern was found 40 km away in lake sediments of roughly the same age. The two species cohabited the same terrain for a substantial period of time. As regards the Koobi Fora trackway, it seems the two hominins plodded through the mud only a few hours apart at most: they were neighbours.

From their respective anatomies they were very different. *Homo erectus* was, apart from having massive brow ridges, similar to us. *Paranthropus boisei* had huge jaws and facial muscles attached to a bony skull crest. So how did they get along? The first was probably omnivorous and actively hunted or scavenged meaty prey: a bifacial axe-wielding hunter-gatherer. Paranthropoids seem to have sought and eaten only vegetable victuals, and some sites preserve bone digging sticks. They were not in competition for foodstuffs and there was no reason for mutual intolerance. Yet they were physically so different that intimate social relations were pretty unlikely. Also their brain sizes were very different, that of *P. Boisei*'s being far smaller than that of *H. erectus* , which may not have encouraged intellectual discourse. Both persist in the fossil record for a million years or more. Modern humans, Neanderthals and Denisovans, as we know, sometimes got along swimmingly, possibly because they were cognitively very similar and not so different physically.

Artists' reconstructions of: left – H. erectus; right – Paranthropus boisei. Credits: Yale University, Roman Yevseyev respectively

Since many hominin fossils are associated with riverine and lake-side environments, it is surprising that more trackways than those of Laetoli and Koobi Fora have been found. Perhaps that is because palaeoanthropologists are generally bent on finding bones and tools! Yet trackways show in a very graphic way how animals behave and interrelate with their environment, for example dinosaurs. Now anthropologists have learned how to spot footprint trace fossils that will change, and enrich the human story.

See also: Ashworth, J. Fossil footprints of different ancient humans found together for the first time. *Natural History Museum News* 28 November 2024; Marshall, M. Ancient footprints show how early human species lived side by side. *New Scientist*, 28 November 2024

The earliest known human-Neanderthal relations

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The first anatomically modern humans (AMH) known to have left their remains outside of Africa lived about 200 ka ago in Greece and the Middle East. They were followed by several short-lived migrations that got as far as Europe, leaving very few fossils or artefacts. Over that time Neanderthals were continually present. Migration probably depended on windows of opportunity controlled by pressures from climatic changes in Africa and sea level being low enough to leave their heartland: perhaps as many as 8 or 9 before 70 ka, when continuous migration out of Africa began. The first long-enduring AMH presence in Europe began around 47 ka ago.

For about 7 thousand years thereafter – about 350 generations – AMH and Neanderthals co-occupied Europe. Evidence is growing that the two groups shared technology. After 40 ka there are no tangible signs of Neanderthals other than segments of their DNA that constitute a proportion of the genomes of modern non-African people. They and AMH must have interbred at some time in the last 200 ka until Neanderthals disappeared. In the same week in late 2024 two papers that shed much light on that issue were published in the leading scientific journals, *Nature* and *Science*, picked up by the world's news media. Both stem from research led by researchers at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. They focus on new DNA results from the genomes of ancient and living *Homo sapiens*. One centred on 59 AMH fossils dated between 45 and 2.2 ka and 275 living humans (Iasi, L. M. N. and 6 others 2024. Neanderthal ancestry through time: Insights from genomes of ancient and present-day humans *Science*, v. **386**, p. 1239-1246: DOI: 10.1126/science.adq3010. PDF available by request to leonardo_iasi@eva.mpg.de). The other concerns genomes recovered from seven AMH individuals from the oldest sites in Germany and Czechia. (Sümer, A. P. and 44 others 2024. Earliest modern human genomes constrain timing of Neanderthal admixture. Nature, online article; DOI: 10.1038/s41586-024-08420-x. PDF available by request to arev_suemer@eva.mpg.de).

Leonardo Iasi and colleagues from the US and UK examined Neanderthal DNA segments found in more than 300 AMH genomes, both ancient and in living people, by many other researchers. Their critical focus was on lengths of such segments. Repeated genetic recombination in the descendants of those individuals who had both AMH and Neanderthal parents results in shortening of the lengths of their inherited Neanderthal DNA segments. That provides insights into the timing and duration of interbreeding. The approach used by Iasi *et al*. used sophisticated statistics to enrich their analysis of Neanderthal-human gene flow. They were able to show that the vast majority of Neanderthal inheritance stems from a single period of such gene flow into the common ancestors of *all* living people who originated outside Africa. This genetic interchange seems to have lasted for about 7 thousand years after 50 ka. This tallies quite closely with the period when fossil and cultural evidence supports AMH and Neanderthals having co-occupied Europe.

Reconstruction of the woman whose skull was found at Zlatý kůň, Czechia. Credit: Tom Björklund / Max Planck Institute for Evolutionary Anthropology.

The other study, led by Arev Sümer, has an author list of 44 researchers from Germany, the US, Spain, Australia, Israel, the UK, France, Sweden, Denmark and Czechia. The authors took on a difficult task: extracting full genomes from seven of the oldest AMH fossils found in Europe, six from a cave Ranis in Germany and one from about 230 km away at Zlatý kůň in Czechia. Human bones, dated between 42.2 and 49.5 ka, from the Ranis site had earlier provided mitochondrial DNA that proved them to be AMH. A complete female skull excavated from Czechia site, dated at 45 ka had previously yielded a high quality AMH genome. Interestingly that carried variants associated with dark skin and hair, which perhaps reflect African origins. Neanderthals probably had pale skins and may have passed on to the incomers genes associated with more efficient production of vitamin D in the lower light levels of high latitudes and maybe immunity to some diseases. Both sites contain a distinct range of artefacts known as the Lincombian-Ranisian-Jerzmanowician technocomplex. This culture was once regarded as having been made by Neanderthals, but is now linked by the mtDNA results to early AMH. Such artefacts occur across central and north-western Europe. The bones from both sites are clearly important in addressing the issue of Neanderthal-AMH cultural and familial relationships.

The new, distinct genetic data from the Ranis and Zlatý kůň individuals reveals a mother and her child at Ranis. The female found at Zlatý kůň had a fifth- to sixth-degree genetic relationship with Ranis individuals: she may have been their half first cousin once removed. This suggests a wider range of communications than most people in medieval Europe would have had. The data from both sites suggests that the small Ranis-Zlatý kůň population – estimated at around 200 individuals – diverged late from the main body of AMH who began to populate Asia and Australasia at least 65 ka ago. Their complement of Neanderthal genetic segments seems to have originated during their seven thousand-year presence in Europe. Though they survived through 350 generations it seems that their genetic line was not passed on within and outside of Europe. They died out, perhaps during a sudden cold episode during the climatic decline towards the Last Glacial Maximum. We know that because their particular share of the Neanderthal genome does not crop up in the wider data set used by Iasi *et al*., neither in Europe and West Asia nor in East Asia. That they survived for so long may well have been due to their genetic inheritance from Neanderthals that made them more resilient to what, for them, was initially an alien environment. It is not over-imaginative to suggest that both populations may have collaborated over this period. But neither survived beyond about 40 ka..

Widely publicised as they have been, the two papers leave much more unanswered than they reveal. Both the AMH-Neanderthal relationship and the general migration out of Africa are shown to be more complex than previously thought by palaeoanthropologists. For a start, the descendants today of migrants who headed east carry more Neanderthal DNA that do living Europeans, and it is different. Where did they interbreed? Possibly in western Asia, but that may never be resolved because warmer conditions tend to degrade genetic material beyond the levels that can be recovered from ancient bones. Also, some living people in the east carry both Neanderthal and Denisovan DNA segments. Research Centres like the Max Planck Institute for Evolutionary Anthropology will clearly offer secure employment for some time yet!

How changes in the Earth System have affected human evolution, migration and culture

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Refugees from the Middle East migrating through Slovenia in 2015. Credit: Britannica

During the Pliocene (5.3 to 2.7 Ma) there evolved in Africa a network of various hominins, with their remains scattered across both the northern and southern parts of that continent. The earliest, though somewhat disputed hominin fossil *Sahelanthropus tchadensis* hails from northern Chad and lived around 7 Ma ago, during the late Miocene, as did a similarly disputed creature from Kenya *Orrorin tugenensis* (~5.8 Ma). The two were geographically separated by 1500 km, what is now the Sahara desert and the East African Rift System. The suggestion from mtDNA evidence that humans and chimpanzees had a common ancestor, the uncertainty about when it lived (between 13 to 5 Ma) and what it may have looked like, let alone where it lived, makes the notion debateable. There is even a possibility that the common ancestor of humans and the other anthropoid apes may have been European. Its descendants could well have crossed to North Africa when the Mediterranean Sea had been evaporated away to form the thick salt deposits that now lie beneath it: what could be termed the 'Into Africa' hypothesis. The better known Pliocene hominins were also widely distributed in the east and south of the African continent. Wandering around was clearly a hominin predilection from their outset. The same can be said about humans in the general sense (genus *Homo*) during the Early Pleistocene when some of them left Africa for Eurasia. Artifacts dated at 2.1 Ma have been found on the Loess Plateau of western China, and Georgia hosts the earliest human remains known from Eurasia. Since then *H. antecessor*, *H. heidelbergensis*, Neanderthals and Denisovans roamed Eurasia. Then, after about 130 ka, anatomically modern humans progressively populated all continents, except Antarctica, to their geographic extremities and from sea level to 4 km above it.

There is a popular view that curiosity and exploration are endemic and perhaps unique to the human line: 'It's in our genes'. But even plants migrate, as do all animal species. So it is best to be wary of a kind of hominin exceptionalism or superior motive force. Before settled agriculture, diffusion of populations in search of sustenance could simply have achieved the enormous migrations undertaken by all hominins: biological resources move and hunter gatherers follow them. The first migration of *Homo erectus* from Africa to northern China by way of Georgia seems to have taken 200 ka at most and covered about ten thousand kilometres: an average speed of only 50 m per year! That achievement and many others before and later were interwoven with the evolution of brain size, cognitive ability, means of communication and culture. But what were the ultimate drivers? Two recent papers in the journal *Nature Communications* make empirically-based cases for natural forces driving the movement of people and changes in demography.

The first considers hominin dispersal in the Palaearctic biogeographic realm: the largest of eight originally proposed by Alfred Russel Wallace in the late 19th century that encompasses the whole of Eurasia and North Africa (Zan, J. *et al.* 2024. Mid-Pleistocene aridity and landscape shifts promoted Palearctic hominin dispersals. *Nature Communications*, ***v.*** **15**, article 10279; DOI: 10.1038/s41467-024-54767-0). The Palearctic comprises a wide range of ecosystems: arid to wet, tropical to arctic. After 2 Ma ago, hominins moved to all its parts several times. The approach followed by Zan *et al*. is to assess the 3.6 Ma record of the thick deposits of dust carried by the perpetual westerly winds that cross Central Asia. This gave rise to the huge (635,000 km^2) Loess Plateau. At least 17 separate soil layers in the loess have yielded artefacts during the last 2.1 Ma. The authors radiocarbon dated the successive layers of loess in Tajikistan (286 samples) and the Tarim Basin (244 samples) as precisely as possible, achieving time resolutions of 5 to 10 ka and 10 to 20 ka respectively. To judge variations in climate in these area they also measured the carbon isotopic proportions in organic materials preserved within the layers. Another climate-linked metric that Zan *et al*. is a time series showing the development of river terraces across Eurasia derived from the earlier work of many geomorphologists. The results from those studies are linked to variations through time in the numbers of archaeological sites across Eurasia that have yielded hominin fossils, stone tools and signs of tool manufacture, many of which have been dated accurately.

The authors use sophisticated statistics to find correlations between times of climatic change and the signs of hominin occupation. Episodes of desertification in Palaearctic Eurasia clearly hindered hominins' spreading across the continent either from west to east of vice versa. But there were distinct, periodic windows of climatic opportunity for that to happen that coincide with interglacial episodes, whose frequency changed at the Mid Pleistocene Transition (MPT) from about 41 ka to roughly every 100 ka. That was suggested in 2021 to have arisen from an increased roughness of the rock surface over which the great ice sheets of the Northern Hemisphere moved. This suppressed the pace of ice movement so that the 41 ka changes in the tilt of the Earth's rotational axis could no longer drive climate change during the later Pleistocene, despite the fact that the same astronomical influence continued. The succeeding ~100 ka pulsation may or may not have been paced by the very much weaker influence of Earth changing orbital eccentricity. Whichever, after the MPT climate changes became much more extreme, making human dispersal in the Palearctic realm more problematic. Rather than hominin's evolution driving them to a 'Manifest Destiny' of dominating the world vastly larger and wider inorganic forces corralled and released them so that, eventually, they did.

Much the same conclusion, it seems to me, emerges from a second study that covers the period since ~ 9 ka ago when anatomically modern humans transitioned from a globally dominant hunter-gatherer culture to one of 'managing' and dominating ecosystems, physical resources and ultimately the planet itself. (Wirtz, K.W *et al.* 2024. Multicentennial cycles in continental demography synchronous with solar activity and climate stability. *Nature Communications*, ***v.*** **15**, article 10248; DOI: 10.1038/s41467-024-54474-w). Like Zan *et al*., Kai Wirtz and colleagues from Germany, Ukraine and Ireland base their findings on a vast accumulated number (~180,000) of radiocarbon dates from Holocene archaeological sites from all inhabited continents. The greatest number (>90,000) are from Europe. The authors applied statistical methods to judge human population variations since 11.7 ka in each continental area. Known sites are probably significantly outweighed by signs of human presence that remain hidden, and the diligence of surveys varies from country to country and continent to continent: Britain, the Netherlands and Southern Scandinavia are by far the best surveyed. Given those caveats, clearly this approach gives only a blurred estimate of population dynamics during the Holocene. Nonetheless the data are very interesting.

The changes in population growth rates show distinct cyclicity during the Holocene, which Wirtz *et al*. suggest are signs of booms and busts in population on all six continents. Matching these records against a large number of climatic time series reveals a correlation. Their chosen metric is variation in solar irradiance: the power per unit area received from the Sun. That has been directly monitored only over a couple of centuries. But ice cores and tree rings contain proxies for solar irradiance in the proportions of the radioactive isotopes ^{10}Be and ^{14}C contained in them respectively. Both are produced by the solar wind of high-energy charged particles (electrons, protons and helium nuclei or alpha particles) penetrating the upper atmosphere. The two isotopes have half-lives long enough for them to remain undecayed and thus detectable for tens of thousand years. Both ice cores and tree rings have decadal to annual time resolutions. Wirtz *et al*. find that their crude estimates of booms and busts in human populations during the Holocene seem closely to match variations in solar activity measured in this way. Climate stability favours successful subsistence and thus growth in populations. Variable climatic conditions seem to induce subsistence failures and increase mortality, probably through malnutrition.

A nice dialectic clearly emerges from these studies. 'Boom and bust' as regards populations in millennial and centennial to decadal terms stem from climate variations. Such cyclical change thus repeatedly hones natural selection among the survivors, both genetically and culturally, increasing their general fitness to their surroundings. Karl Marx and Friedrich Engels would have devoured these data avidly had they emerged in the 19th century. I'm sure they would have suggested from the evidence that something could go badly wrong – negation of negation, if readers care to explore that dialectical law further . . . And indeed that is happening. Humans made ecologically very fit indeed in surviving natural pressures are now stoking up a major climatic hiccup, or rather the culture and institutions that humans have evolved are doing that.