REPORT

PALEOANTHROPOLOGY

Middle Pleistocene *Homo* behavior and culture at 140,000 to 120,000 years ago and interactions with *Homo sapiens*

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Fossils of a Middle Pleistocene (MP) *Homo* within a well-defined archaeological context at the open-air site of Nesher Ramla, Israel, shed light on MP *Homo* culture and behavior. Radiometric ages, along with cultural and stratigraphic considerations, suggest that the fossils are 140,000 to 120,000 years old, chronologically overlapping with *H. sapiens* in western Asia. Lithic analysis reveals that MP *Homo* mastered stone-tool production technologies, previously known only among *H. sapiens* and Neanderthals. The Levallois knapping methods they used are indistinguishable from that of concurrent *H. sapiens* in western Asia. The most parsimonious explanation for such a close similarity is the cultural interactions between these two populations. These findings provide evidence of contacts and interactions between *H. sapiens* and MP *Homo*.

The emergence and expansion of *Homo sapiens* during the late Middle Pleistocene (MP) in Africa is associated with complex behaviors and technologies that typify the Middle Stone Age (MSA) (*1*–*5*). One of the major technological innovations of the MSA is the Levallois technology that emerged and spread across most of the African continent ~300,000 years (300 ka) ago (*1*, *6*). During the late MP, the centripetal Levallois method was used as the main mode for the production of flakes and blades in many sites in Africa and western Asia (Fig. 1 and table S1). The centripetal Levallois method is a well-structured technical process executed using a set of distinct and repetitive actions (*7*). The earliest evidence of the centripetal Levallois technology was reported in the early MSA sites at the Kapthurin and Gademotta Formations (dated to 250 to 200 ka and ~276 ka, respectively) (*2*, *8*). The MSA in general, and centripetal Levallois technology in particular, were found to be associated with the *H. sapiens* remains at Omo Kibish, Herto, and Aduma (*9*–*11*) (tables S1 and S2).

The earliest occurrences of *H. sapiens* in southwest Asia (~180 ka) are associated with Middle Paleolithic industries and Levallois technology (*12*). During Marine Isotope Stage (MIS) 5 (130 to 71 ka), all *H. sapiens* fossils in western Asia were found to be associated with the centripetal Levallois method (*13*–*17*). Given the prominent presence of the centripetal Levallois method in association with *H. sapiens*, it was often used as a marker of *H. sapiens* dispersal into western Asia during MIS 5 (*17*–*20*). In western Europe, the centripetal Levallois technology occurs sporadically from MIS 8. A systematic use of the centripetal Levallois method in Europe is recorded at the end of MIS 5 and during MIS 4 (text S6).

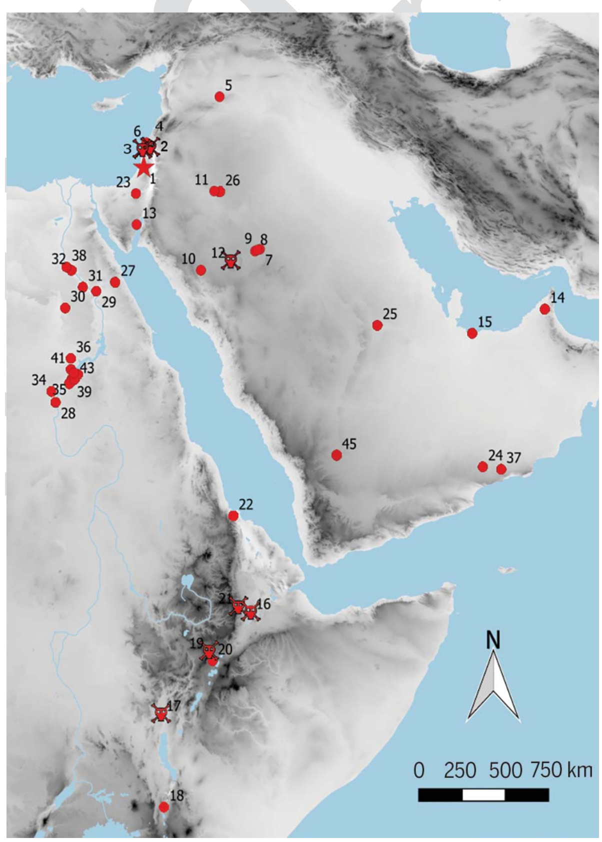

Fig. 1. Lithic assemblages with a marked component of Centripetal Levallois dated to MIS 5 and 6 in the Near East and eastern and northeastern Africa. Sites with human remains are denoted by a skull. The Nesher Ramla site is denoted by a star. The lithic assemblages marked on the map belong to different technocomplexes (see table S1 for a description of the sites and their technocomplexes). Digital elevation data are courtesy of GTOPO 30, USGS.

Two recently discovered human fossils at Nesher Ramla (*21*) provide evidence of the presence of archaic MP *Homo* in the Levant in a Middle Paleolithic context, during a period when the area was presumably inhabited by only *H. sapiens*. This suggests a long overlapping period between these two *Homo* groups (*21*). Our study of the lithic assemblages from stratigraphic Unit VI of the site, associated with the Nesher Ramla fossils (Fig. 2, B to D), indicates that late MP *Homo* fully mastered the Levallois technology. Here, we report on the cultural context, chronometric ages, and stone-tool assemblages associated with this newly discovered *Homo*.

The Nesher Ramla karst sinkhole (Fig. 2A) is located in central Israel within a chalk bedrock of Senonian age. Middle Paleolithic cultural remains were uncovered in an 8-m-thick sequence, 107.5 to 99.5 m above sea level, ~12 m below the rim of the depression (*22*). The cultural sequence consists of six archaeological units (Units I to VI; Fig. 2, B and D, and text S1). The lowermost Unit VI, the focus of this study, is ~1 m thick and is subdivided into five layers (VI I1 to I5). A right parietal human bone and an almost complete human mandible (*21*) were found in layer VI I3, which is located in the middle of a sedimentological sequence of Unit VI (Fig. 2, B and D, and fig. S1, A and B).

A combination of electron spin resonance/uranium series (ESR/U-series), thermoluminescence (TL), and optically stimulated luminescence

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(OSL) dating methods was applied to date the site and the human fossils (tables S3 to S5 and text S2). Three herbivorous teeth unearthed from Unit VI (I2 and I3) were analyzed using a combined ESR/U-series approach to overcome the changes in the uranium content of the dental tissues that may have occurred since the burial time. The obtained ages range from 114 ± 12 ka to 140 ± 9 ka, leading to a weighted mean of 126 ± 6 ka. The same approach yielded ages between 120 ± 9 ka and 128 ± 8 ka for animal teeth recovered in the overlying layer (Unit V)
F3 with a weighted mean of 122 ± 3 ka. Figure 3A and table S4 show equivalent doses, dose rates, and uranium uptake parameters for the enamel and dentine tissues (p- or n-values for the U-series and the Accelerating Uptake model, respectively; see text S2), and all the ESR/U-series ages. In addition, the TL dating method was applied to nine burnt flint samples collected from Unit V, ~50 cm above the fossils. The TL ages (Fig. 3A, table S3, and fig. S2) range from 191 ± 13 ka to 104 ± 11 ka; however, because these samples belong to a well-defined 20- to 40-cm-thick archaeological layer, they are likely to be coeval. Thus, the 191 ± 13 ka age appears to be an anomaly, confirmed by simple statistical tests (Chauvenet's criterion or the χ^2 test). When this result is ruled out as an outlier, the individual ages of the eight remaining flints are compatible within a 2σ error interval, and their weighted mean is 128 ± 4 ka. Moreover, because these samples have been subjected to similar external dose rates (table S3B shows small intersample external dose variations), an isochron analysis was performed (fig. S2A), resulting in an isochron age of 135 ± 13 ka, in agreement with the weighted mean TL age. This indicates that the external dose rates used for calculating the TL individual ages are most likely correct. The TL dates are indistinguishable from the ESR/U-series ages obtained for the same unit (Unit V), and they are in agreement with the weighted mean ESR/U-series date of 126 ± 6 ka for Unit VI (table S4). According to these chronometric results, Unit VI can then be confidently assigned an age of at least 120 ka, in agreement with the previously published OSL ages obtained for the whole sequence (*22*), indicating that the human occupation of the site occurred at the transition between MIS 6 and MIS 5.

The studies of the site-formation processes and the lithic assemblages support the results obtained by radiometric dating. Both Units V and VI exhibit similar sedimentological and micromorphological characteristics (fig. S3 and text S1). No hiatus or unconformities between the two units were observed. Micromorphological and sedimentological analyses suggest a continuous deposition by similar depositional mechanisms (*23*). Thus, we conclude

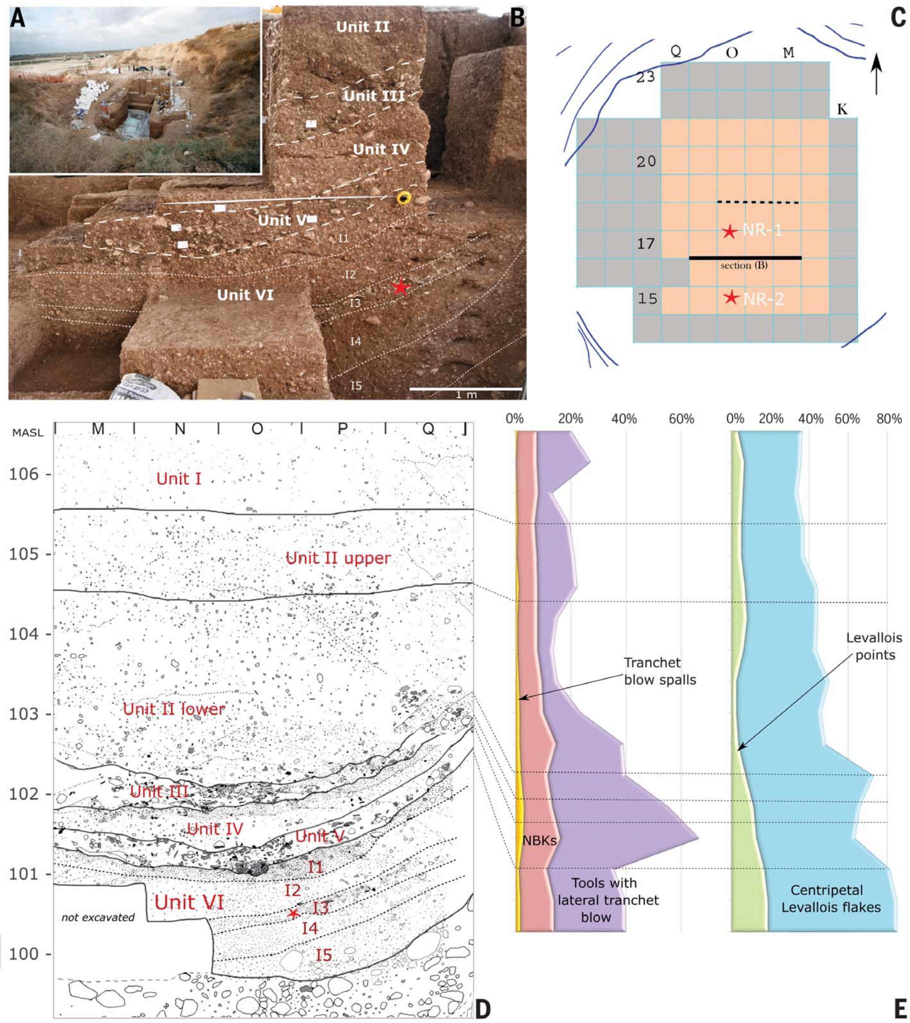

Fig. 2. The Nesher Ramla site. (**A**) General view of the site from east to west. (**B**) Photo of the stratigraphic section showing Units IIb to VI. The red star denotes the location of the MP *Homo* parietal bone. (**C**) The plan of the site. Excavated squares are denoted in gray. The studied lithic assemblage derives from the squares denoted in light brown. Red stars denote the location of the MP *Homo* fossils. The solid line denotes the location of the section shown in (B) and (D). The dashed line denotes the location of the section shown in fig. S1A. (**D**) Stratigraphic section of Nesher Ramla with its various units. The red star denotes the location of the parietal bone. (**E**) Fluctuations in the frequencies of the main lithic categories (lateral *tranchet* blow spalls from the total assemblage; tools with a lateral *tranchet* blow from the total retouched tool assemblage; Levallois points and centripetal Levallois flakes from the total Levallois assemblage). NBK, naturally backed knives.

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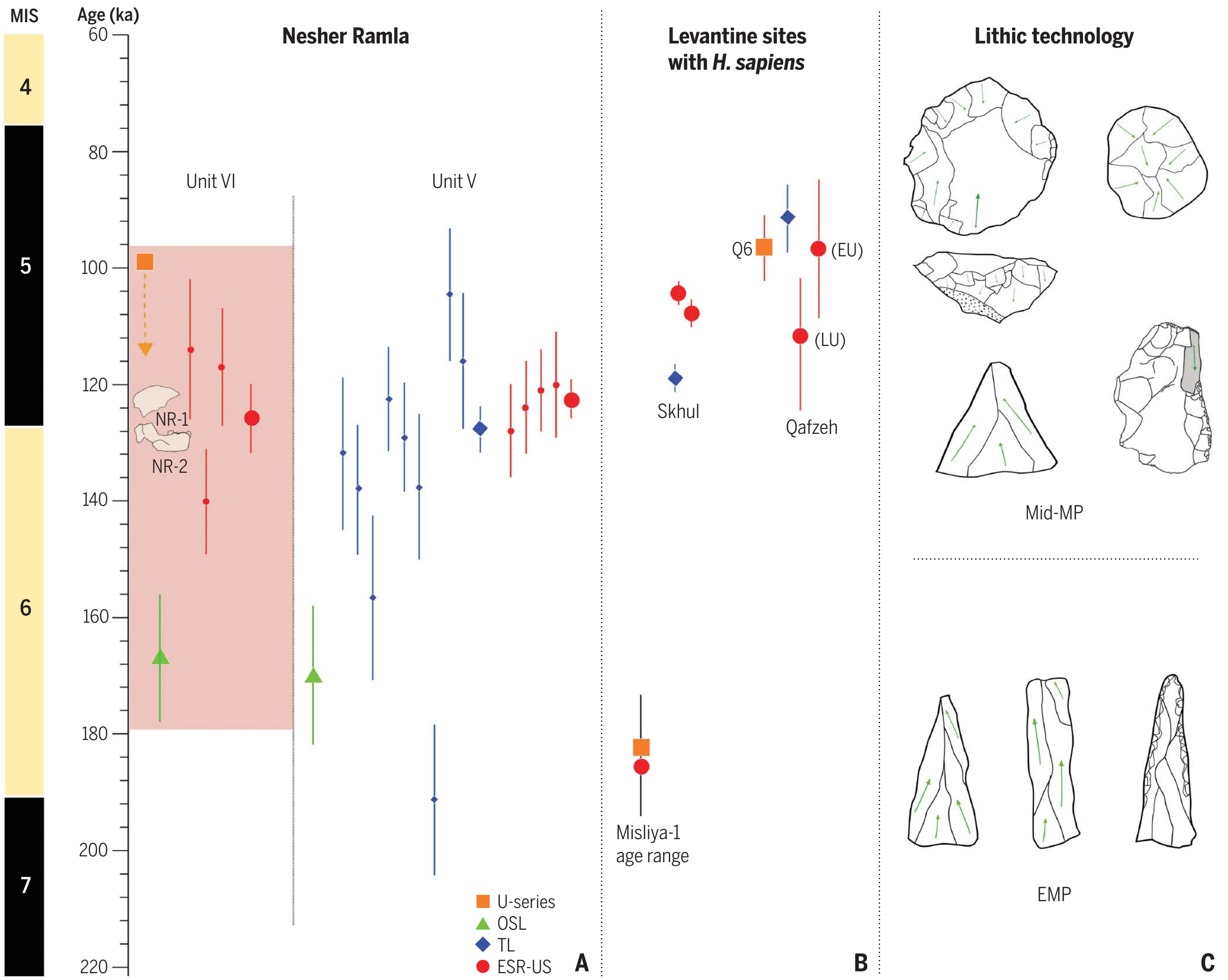

Fig. 3. Chronology and position of the Nesher Ramla site in the Levantine Middle Paleolithic chrono-cultural framework. (**A**) Dating results for Units VI and V of the Nesher Ramla site. Large symbols represent weighted mean ages for ESR/U-series (circles), TL (diamonds), and OSL (triangles). The orange square represents the minimum age obtained by the U-series method. NR-1 and NR-2 denote the MP *Homo* remains. (**B**) Chronology of the Middle Paleolithic sites with *H. sapiens* remains in the Levant. On the basis of mean ages (table S1), Q6 is the direct age of the Qafzeh 6 human fossil and Misliya 1 is the direct age of the Misliya *H. sapiens* maxilla. (**C**) Major lithic characteristics of Early Middle Paleolithic (EMP) and the middle Middle Paleolithic (mid-MP) in the Levant (*15*, *24*, *25*) (text S6).

that no gap in deposition or changes in the depositional environment occurred between the accumulation of Units VI and V. Fast and continuous deposition is also supported by the stone tools, which show similar characteristics in both units and therefore may have been manufactured by hominins with a shared cultural tradition (Fig. 2 and texts S3 and S4). Finally, Nesher Ramla's industry shows a clear similarity with the MIS 5 industries of the region (*24*) (text S6); it clearly differs from the regional Early Middle Paleolithic (EMP) industries (*25*), dating from 270 to 140 ka (*26*) (Fig. 3, B and C, and text S6). Taking into account the radiometric ages obtained and the depositional and cultural considerations, the most likely age for the Nesher Ramla *Homo* is ~140 to 120 ka.

The presence of some butchered faunal remains in anatomical articulation (fig. S1, D and E), the lithic refitting, and the in situ features (such as hearths and ash piles) indicate in situ human activities during the accumulation of the Nesher Ramla archaeological sequence (*23*) (text S5). The faunal assemblage of Unit VI is dominated by tortoises and ungulates. The faunal assemblage was modified by human hunting and processing, as manifested by numerous cutmarks and hammer-stone percussion marks. All skeletal parts are represented even for the largest ungulates, which testify to the hunting activities that took place at or very near the sinkhole. The presence of anatomical articulations, unbiased skeletal part profiles, and the virtual absence of abrasion indicate in situ accumulation within the sinkhole. The assemblage is generally composed of open-landscape taxa such as gazelle, equids, and ostrich, as well as animals inhabiting a wider variety of habitats, such as aurochs and boar, and relatively small proportions of woodland-adapted fallow deer. This suggests a generally open landscape near Nesher Ramla during the accumulation of Unit VI. The ungulate composition and the dominance of tortoises are similar to other Lower Sequence units (text S5).

About 6000 artifacts (>2 cm) were excavated from Unit VI of Nesher Ramla. The lithic assemblage from Unit VI I2 to I5, directly associated with the Nesher Ramla fossils, consists of 2184 artifacts larger than 2 cm (Fig. 2C, tables S6 and S7, and text S3). All studied

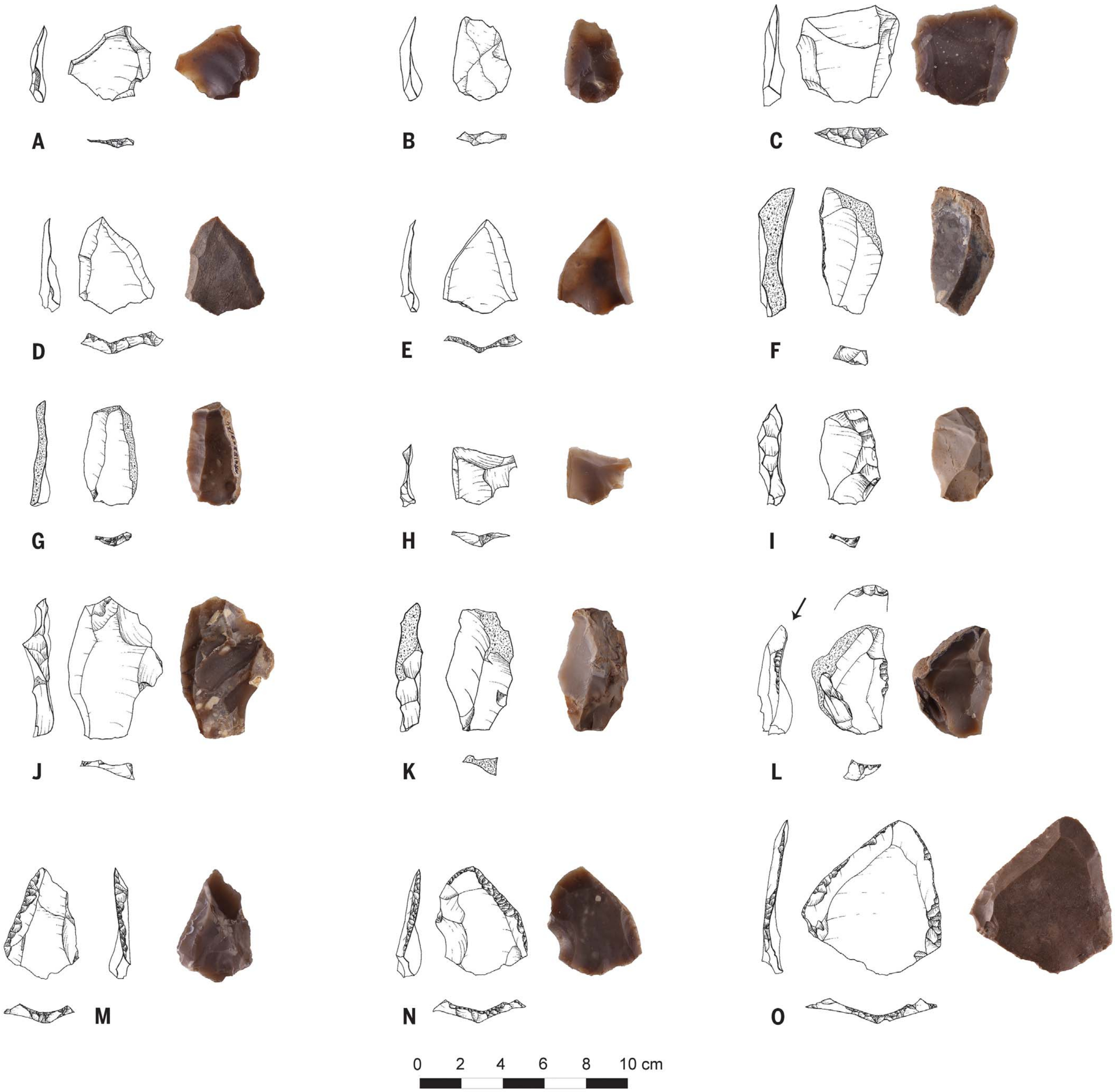

Fig. 4. Lithic assemblage of Unit VI I2 to I5. (a to c) Centripetal Levallois flakes; (d and e) Levallois points; (f and g) naturally backed knives; (h) pseudo-Levallois point; (i to k) *débordant* flakes; (l) tool with a lateral *tranchet* blow; (m and n) sidescrapers; (o) retouched Levallois point.

sublayers in which the fossils have been found, including sublayer I3, exhibit similar technological characteristics (table S6). The assemblage is made of flint. The hominins used local high-quality flint from the Mishash Formation (fig. S4 and text S3). As indicated by the presence of cores, primary elements, flakes, and core maintenance products, Mishash flint was knapped at the site. The cores are completely exhausted, which suggests that hominins knapped the cores to their maximum potential. The flint, brought from distances that extend 10 km from the site, appears in minor frequencies in all technological categories; however, it is more frequent among retouched pieces, which implies that hominins carried the retouched tools as a part of their mobile toolkit (table S8).

The Nesher Ramla *Homo* mainly used the centripetal Levallois method (figs. S5 to S7 and tables S6, S7, and S9). The lithic assemblage of Unit VI is dominated by round or rectangular wide Levallois flakes with centripetal and orthogonal scar patterns and well-prepared striking platforms (Fig. 4, fig. S5, tables S9 and S10, F4 and text S3). The convexity of the debitage surfaces of the Levallois cores was achieved and maintained through centripetal preparation. The assemblage exhibits a high frequency of Levallois *débordant* flakes with centripetal and orthogonal scar patterns as well as pseudo-Levallois points and flakes (Fig. 4, fig. S7, and table S9). These classic predetermining

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by-products of the centripetal Levallois reduction system were used to maintain the convexities of the dorsal surfaces of the Levallois cores. After the preparation of convexities, the predetermined flakes were produced by the preferential method and the recurrent centripetal Levallois method (fig. S5). The centripetal Levallois method exhibits similar technological characteristics throughout the archaeological sequence of Nesher Ramla (tables S11 and S12 and text S4).

The production of Levallois points is an auxiliary reduction system recorded in Unit VI (tables S6 and S7). Levallois points occur in various frequencies throughout the site's stratigraphic sequence but are most frequent in Unit VI (table S11). Levallois points were produced by a preferential unidirectional convergent Levallois method and are mostly classical Y-shaped, with a rare use of bidirectional removals aimed at correcting the distal convexity (Fig. 4, figs. S5 and S8, and text S3). The points are symmetrical, flat, and broad-based, derived from a preferential mode of production.

Some additional distinct features of the Nesher Ramla assemblage are the systematic production of naturally backed knives and the extensive use of a lateral *tranchet* blow technique for producing tools with partly retouched and partly sharped edges (Fig. 4, figs. S7, S9, and S10, and table S13). These distinctive characteristics of the Nesher Ramla industry occur in varying frequencies throughout the entire archaeological sequence of the site, along with the centripetal Levallois technology and Levallois point production (Fig. 2E and text S4). The use of the same technologies and the production of the same set of artifacts suggest a cultural continuity in the area during the accumulation of the 8-m-thick archaeological sequence (Fig. 2, D and E, and tables S11 and S12).

MP *Homo* fossils often lack a cultural context, and their behavior and technology remain poorly known. Nonetheless, it is commonly suggested that MP *Homo* produced Lower Paleolithic industries [Acheulian, or core-on-flakes (*27*–*32*)]. The evidence from Nesher Ramla demonstrates that late MP *Homo* fully mastered advanced Levallois technology that until only recently was linked to either *H. sapiens* or Neanderthals. The use of the centripetal Levallois method by the Nesher Ramla *Homo* suggests caution in using lithic technology as a marker for the presence and dispersals of *H. sapiens* out of Africa in MIS 5. This is consistent with recent views that MP *Homo* could be one of the makers of MSA industries in Africa (*33*). The origin of the centripetal Levallois technology in the Levant is debatable (*13*–*15*, *17*–*20*). The EMP (250 to 140 ka) industries in the Levant exhibit an entirely different technological set featuring the dominance of blades produced by non-Levallois laminar methods and the production of Levallois blanks using convergent unidirectional and bidirectional Levallois methods. The EMP industries show no evidence of the systematic use of centripetal Levallois methods (text S6). Therefore, we suggest that the centripetal technology of the Levantine MIS 5 sites is not of local origin and that its most probable source is East and North Africa, where it represents a central component in the MIS 6 and MIS 5 assemblages (Fig. 1 and tables S1 and S2).

The centripetal Levallois technology used by the Nesher Ramla *Homo* clearly resembles the technology used in the *H. sapiens* sites of Qafzeh and Skhul, the MIS 5 sites in Arabia, and the MSA sites in North and East Africa, including sites where the remains of *H. sapiens* were found (Fig. 1, tables S1 and S2, and text S6). The resemblance lies in the fine details such as a similar mode of preparing the convexities and a similar way of processing the cores so as to produce predetermined Levallois flakes with a round or rectangular shape (tables S11 and S12 and text S6). This resulted in similar types of products, such as centripetal Levallois cores, centripetal Levallois flakes, *débordant* flakes with a centripetal scar pattern, and pseudo-Levallois flakes and points. Furthermore, Nesher Ramla hominins shared the preferential convergent unidirectional method for producing Levallois points with other Levantine MIS 5 sites (text S6) (*15*). In both Qafzeh Cave and Nesher Ramla, the preferential method is the most common one used in the production of flat and short Levallois points, as opposed to the elongated Levallois points with abrupt edges known in the Levantine EMP (*25*). The production of Levallois points by a unidirectional convergent Levallois method is rare in Africa during MIS 5, which suggests that it is mostly a Levantine feature shared by both MP *Homo* at Nesher Ramla and *H. sapiens* at the Qafzeh and Skhul caves.

Our results clearly show that *H. sapiens* and MP *Homo* shared core reduction technology during MIS 5 in a small region such as the Levant. We contend that cultural diffusion and interaction across *Homo* populations is the most likely reason for such a close cultural similarity between MP *Homo* and *H. sapiens*. These results are consistent with a growing body of genetic studies suggesting that a gene flow existed between divergent archaic *Homo* populations and *H. sapiens* during the late Middle and early Late Pleistocene (*34*, *35*). Our findings provide archaeological support for close cultural interactions between different human lineages during the Middle Paleolithic period and suggest that contacts between MP *Homo* and *H. sapiens* had already occurred prior to 120 ka.

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SUPPLEMENTARY MATERIALS

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Supplementary Text
Figs. S1 to S10
Tables S1 to S13
References (*36*–*190*)

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