A forager–herder trade-off, from broad-spectrum hunting to sheep management at Aşıklı Höyük, Turkey

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Aşıklı Höyük is the earliest known preceramic Neolithic mound site in Central Anatolia. The oldest Levels, 4 and 5, spanning 8,200 to approximately 9,000 cal B.C., associate with round-house architecture and arguably represent the birth of the Pre-Pottery Neolithic in the region. Results from upper Level 4, reported here, indicate a broad meat diet that consisted of diverse wild ungulate and small animal species. The meat diet shifted gradually over just a few centuries to an exceptional emphasis on caprines (mainly sheep). Age-sex distributions of the caprines in upper Level 4 indicate selective manipulation by humans by or before 8,200 cal B.C. Primary dung accumulations between the structures demonstrate that ruminants were held captive inside the settlement at this time. Taken together, the zooarchaeological and geoarchaeological evidence demonstrate an emergent process of caprine management that was highly experimental in nature and oriented to quick returns. Stabling was one of the early mechanisms of caprine population isolation, a precondition to domestication.

caprine domestication | zooarchaeology | stabling deposits

The Neolithic brought fundamental transformations to human society and humans' place in natural systems. Early villages reorganized rapidly around new ways of extracting food from the environment, and animal and plant management seem to lie at the heart of many of these changes. The initial conditions of village community evolution are elusive, however, because late forager and forager-producer transition sites are few, in contrast to the abundant records of the later Neolithic. Known exceptions in central Turkey are the early occupations at Aşıklı Höyük in Cappadocia, the ninth millennium occupations at Pınarbaşı and Boncuklu in the Konya Basin (1, 2), and the late Epipaleolithic occupations in Pınarbaşı Rockshelter in Konya and Direkli Cave in Kahramanmaraş (3, 4).

Few of the early Pre-Pottery Neolithic (PPN) communities display precocious histories of animal management, although plant cultivation was widespread. Regional contrasts in the early PPN testify to the volatile and locally variable nature of "neolithization" across the Middle East (1, 5–21). Only later in the PPN were certain staple animal foods truly domesticated, some in energetically powerful combinations with plants that would fuel the expansion of Neolithic systems into other world regions.

Like the opposing faces of Janus, there are two temporal aspects from which one may view Neolithic origins. Comparisons to the more recent have received the bulk of archaeologists' attention thanks to an abundance of data on the later PPN and historic stock-keeping practices. Looking to the early Neolithic from a deeper past, the Epipaleolithic, is the view less often taken. Comparison data are less easy to come by, but the advantage of this forward-looking view is its consistency with the direction of evolution itself. As revolutionary as neolithization and the emergence of village communities may have been, the Epipaleolithic and PPN are linked by widespread human attempts to optimize the growth of food species and to extend their seasonal availability through storage. Evolution can occur only through existing pathways of opportunity and Epipaleolithic lifeways were exceptionally rich in strategic and cultural variety. The observation of multiple origins in sheep domestication (22), for example, illustrates the need to examine local histories in a ground-upward manner as a complement to interregional comparisons of culture change (8).

Here we examine the formative conditions of the forager-producer transition at Aşıklı Höyük through the lens of animal exploitation. This site preserves a surprisingly detailed record of human–animal interactions in a formative settlement (23). The story of socioeconomic change begins in Level 5, which is not yet excavated. Nonetheless, the cultural deposits of Level 4 reveal important early trade-offs within the meat diet that are accompanied by evidence of human manipulation, or management, of caprine (sheep and goat) survivorship. Although management practices may give rise to domestic taxa after many generations, it is the early elements of these coevolutionary relations that interest us here; hence, we must look to evidence other than morphologic changes. Zooarchaeological analysis provides information about prey choice and ungulate age-sex structures, and geoarchaeological (micromorphology and phytolith) analyses provide information on physical interactions between humans and ungulates within the confines of the settlement.

Background

Aşıklı Höyük (AH) sits directly on a floodplain of the Melendiz River (elevation 1,119 m) (Fig. 1) in Cappadocia, a volcanic landscape carved by wind, water, and humans. This short river originates in the Melendiz Mountains (2,963 m) and drains westward into the salt lake known as Tuz Gölü. Beyond the isolated Melendiz highlands lies the great Taurus mountain chain. Rolling plains and upland meadows of the region once supported wild aurochs (*Bos primigenius*), horse (*Equus ferus*),

Significance

This article provides original results on the formative conditions of sheep domestication in the Near East. To our knowledge, none of the results has been published before, and the results are expected to be of wide interest to archaeologists, biologists, and other professionals interested in evolutionary and cultural processes of animal domestication.

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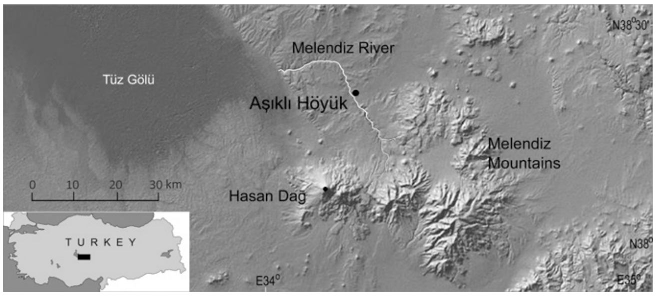

Fig. 1. Location of Aşıklı Höyük on the Melendiz River in western Cappadocia (Central Anatolia), Turkey.

onager (*Equus hemionus hydruntinus*), wild boar (*Sus scrofa*), deer (*Cervus elaphus*, *Capreolus capreolus*, *Dama dama*), goats (*Capra aegagrus*), and sheep (*Ovis orientalis*).

AH is an artificial mound composed of 16 m of anthropogenic deposits (24, 25). Levels 4 through 2 preserve a remarkable history of architectural transitions, from semisubterranean round buildings to densely packed free-standing rectangular buildings (23, 26). The later PPN of Level 2 has occupied nearly two decades of research under the direction of Ufuk Esin and subsequently Nur Balkan-Atlı of Istanbul University. Here, author H.B. (27) found possible evidence for "proto-domestication" (*sensu* management) of sheep and goats based on age and sex ratios. Domesticated cereal grains were in cultivation at this time (24, 25), although domestic variants are less common in the botanical assemblages than morphologically wild grains and other plant foods (28). Radiocarbon dates for Level 2 range between 8000 and 7500 cal B.C. (29).

Balkan-Atlı and her colleagues concluded their work at AH in 2004 by digging a deep exploratory trench into the northern edge of the mound. This trench passed through the 2-m-thick deposits of Level 3, which contain widely spaced trapezoidal or semioval structures. The trench also penetrated the top of Level 4, the architecture of which is similar to that of Level 3 but with more uniformly oval-round contours. Recent archaeobotanical studies have identified some domestic emmer and einkorn wheat alongside wild morphs in upper Level 4. This occupation is roughly coeval with the early occupations at Pınarbaşı and Boncuklu (8540–8230 cal B.C.) (see refs. 1 and 2). Levels 5 through 4 in AH arguably represent the birth of the PPN in Central Anatolia (30).

In 2010, M.Ö. of Istanbul University began a new excavation at AH with detailed spatial recording of horizontal and stratigraphic exposures, and complete recovery of artifacts, fauna and floral materials via fine screening and flotation techniques (4-mm and 2-mm mesh). The sediments are excavated in a series of shallow units that follow human-defined spaces and vertical units within stratigraphic levels. Only a fraction of the total settlement is visible in the deep (4GH) trench, but the exposed area of approximately 10 × 15 m presents a startling variety of semi-isolated structures, diverse outdoor features, work spaces, and middens. Radiocarbon assays of short-lived burnt plant remains in combustion features indicate that the upper part of Level 4 spans approximately 8400–8100 cal B.C. Level 5 is not yet excavated, but a burned layer exposed by the river in the mound's western base is reliably dated to 9010 ± 200 cal B.C. The available dates therefore bracket the bulk of the Level 5–4 sequence. As it happens, these dates fall within two separate plateaus in the radiocarbon calibration curve (Figs. S1 and S2 and Table S1), raising the uncertainty associated with the determinations. Radiocarbon dating work continues for the intervening deposits in AH, for which plateau effects are expected to be less problematic. Plant macrofossils and abundant groundstone artifacts in upper Level 4 indicate heavy use of cereal grasses, pulses, hackberry, nuts, and other seeds. It seems likely on these grounds that the site's placement on the river floodplain was predicated upon an already heavy commitment to plant cultivation.

Results

A wide range of animals were hunted during the occupations of upper Level 4, indicating a diversified meat diet (Table S2). Large prey included goats, aurochs, red deer, boar, horse, onager, roe deer, and fallow deer, but sheep most of all. Among the small prey species hunted, hares (*Lepus capensis*) and river fish (Cyprinidae carps) were particularly important, but tortoises (*Testudo graeca*) and pond turtles (*Emys/Mauremys* sp.), hedgehogs (*Erinaceus* sp.), bustards (*Otis tarda*), partridges (*Alectoris chukar*), and water birds (e.g., ducks, Anatidae) were also eaten. Other large birds, such as common crane (*Grus grus*), owls (Strigidae), and raptors (Falconiformes) were exploited on occasion, through probably more for raw materials than for food.

A faunal trend through Levels 4–2 (Fig. 2) reveals a strategic trade-off in the meat diet, from a broad-spectrum strategy that emphasized diverse wild small animals and ungulates to a concerted exploitation of caprines in particular. Caprines constitute less than half of the total number of identified skeletal specimens (NISP) in upper Level 4, but caprines increase gradually to 85–90% by the end of the time series in upper Level 2. The caprines were mainly sheep, which outnumbered goats by a factor of three or more in all periods. The incidence of carnivores hunted by humans and small pests (toads and mice) that entered the site voluntarily changes comparatively little over this span. The contribution of small game declines fastest between Levels 3C and 3B, but this difference is taken up by wild noncaprine ungulates, without interrupting the gradual rise in caprine importance. The replacement of diverse wild taxa with caprines at AH suggests a local, autochthonous evolution of dietary practices. These developments are consistent with faunal patterns observed in early PPN sites in the northern Euphrates region, where caprine- and possibly pig-management practices arose by approximately 8400 cal B.C. (11).

The caprines and aurochs from AH upper Level 4 display a notable bias toward immature individuals (50% and 53%, respectively) based on unfused metapodials or tibias; this bias is not present in the other ungulate species (Tables S3 and S4). Fig. 3 presents a broader, diachronic comparison of the percentages

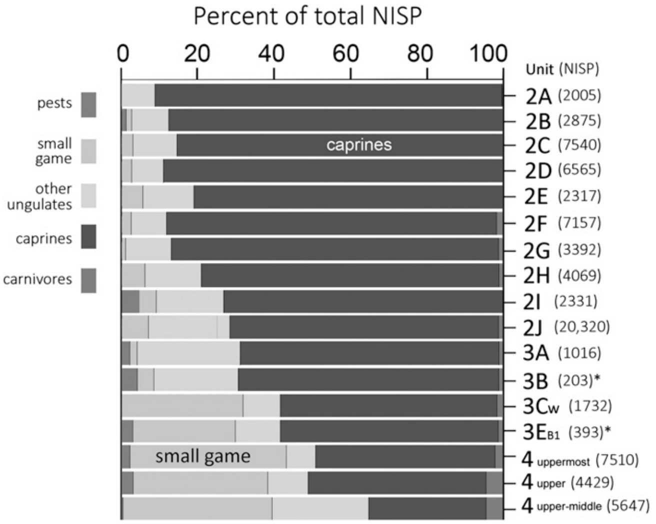

Fig. 2. Variation in the representation of five major animal categories in the faunal assemblages from Level 2 through upper Level 4 of AH based on NISP. *Note small sample size.

of unfused first-phalanges and distal metapodials (which fuse sequentially) for diverse artiodactyl species, including wild caprines, from eastern Mediterranean and Anatolian sites. Epipaleolithic prey age selection seldom differed from that of the Upper and Middle Paleolithic periods. There are, however, anomalous biases to mountain gazelle fawns and young juveniles (*Gazella gazella*) during the early Natufian at Hayonim Cave (31), one of the first sedentary communities of the Levant. The same bias is true for the caprines from AH upper Level 4. Because metapodials are relatively uncommon in the AH sample and the element was heavily recruited for bone tools, the fusion rates for the more common distal tibia are also considered; these results are more in line with the Natufian gazelles. Sedentism seems to have exerted a unique impact on the exploitation of the young of staple ungulate species, regardless of whether that species came to be domesticated.

Another interesting feature of the AH upper Level 4 ungulates concerns the proportion of fetal to neonate remains. Neonate remains occur along with adults in the equids, aurochs, and caprines (Table 1). Only the caprine remains also include fetuses. Nearly one-third of lambs/kids in the caprine death assemblage perished while in utero. It is very unlikely that the absence of fetal bone from the samples of *Bos* and *Sus* is a result of sampling error alone (Table S5). Because of the small number of equid bones, we cannot be certain that the absence of fetal specimens is not a sampling effect in this case, although there is only a 14.4% chance that this is the reason.

An expanded view of caprine survivorship based on bone fusion over the first 2 y of life sets the AH upper Level 4 assemblages apart from both the Epipaleolithic and other PPN assemblages (Fig. 4). Three states of bone development—neonate, unfused/partly fused, and fully fused—are considered for a series of skeletal elements, ordered according to the average age at which each normally fuses (following ref. 32). The AH upper Level 4 assemblages are subdivided consecutively into uppermost and midupper Level 4 samples. These assemblages are very different to late Epipaleolithic sheep-dominated caprines from Öküzini 3–5 in the western Taurus (33). About 40–50% of the AH caprines died before reaching adulthood, whereas only about 20% of the Epipaleolithic caprines died short of adulthood (Fig. 4*A*). The AH Level 4 assemblages are also distinct from PPN caprine assemblages (Fig. 4*B*) from Suberde (34) and the Level 2 occupations at AH (27). The mortality peak after 6 mo of age but before 12 mo most clearly sets the AH Level 4 assemblages apart from all others in this comparison.

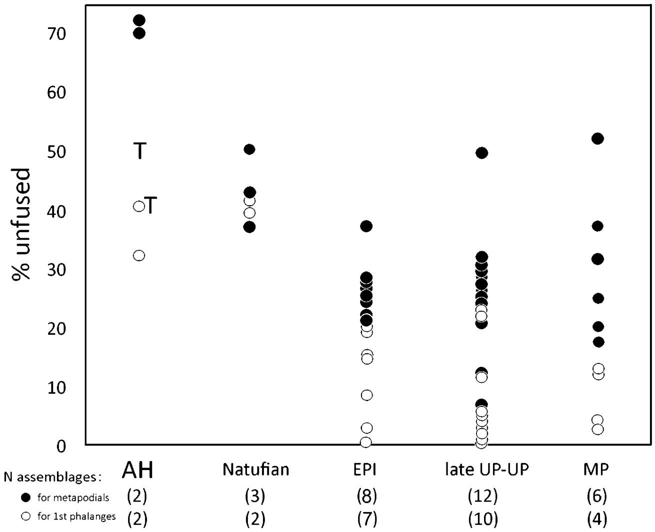

Fig. 3. Comparison of caprine fusion rates in AH upper Level 4 for first phalanges and distal metapodials to patterns in earlier artiodactyl assemblages (mountain gazelle, roe deer, fallow deer, or caprines). Other cases are from Karain and Öküzini 5 (33), Hallan Çemi, and Üçağızlı Cave I and Üçağızlı Cave II in Turkey, and Hayonim Cave, Hilazon Tachtit, Meged Rockshelter, and Kebara Cave in the southern Levant (31, 40). EPI, Epipaleolithic; MP Middle Paleolithic; T, Distal tibia, which fuses around same time as the metapodials; UP, Upper Paleolithic.

Table 1. NISP among the infantile ungulate remains in upper Level 4

Taxon	NISP fetus	NISP neonate	NISP fetus/neonate
Equidae	0	10	2
Bos	0	18	3
Caprines	30	64	107
Sus	0	22	4
Cervidae	0	0	0

Differences between other taxa and the caprines are significant at the 0.05 level of probability, except for Equidae. Age determinations are based on aged reference skeletons; not all specimens could be determined (hence the fetus/neonate category).

Dental-based mortality patterns are difficult to link directly to the fusion results because of the different parameters involved, but the dental data are important for examining mortality patterns across the full potential lifespan, as well as within the juvenile period. The age stages used in Fig. 5 follow Payne (35), with modifications by Grant (36) for milk teeth. Dental counts (minimum number of element, MNE) combine isolated and articulated mandibular teeth (following ref. 37) (Table S6). Young caprines from AH upper Level 4 were harvested at nearly every age stage over the first 24 mo of life (Fig. 5*A*), based on eruption-wear data for the deciduous lower fourth premolar (dP_4). Culling was generally continuous, but an abrupt peak occurs midway through the functional life of the milk tooth, probably leading into winter. Moderate levels of culling continued thereafter.

Fig. 5*B* shows that most adult deaths (across stages E–I) occurred between 2 and 4 y of age, or in stages E–F. Fig. 5*C* compares AH caprine survivorship to other early to mid-PPN and Epipaleolithic caprine assemblages using a Kolmogorov–Smirnov test. In all cases the *D* statistic was less than the 0.05 rejection threshold (Table S7), indicating no statistically significant differences in the distribution among the seven age categories of the AH4 caprine age structure and those from PPN Göbekli Tepe (16), Cafer Höyük (38), Tell Aswad (39), and Tell Halula [Sana Segui (37)]. Moreover, the AH4 caprine survivorship pattern is not statistically different from the early Epipaleolithic caprines of Karain B 1 and 2 (17,800–17,000 cal B.C.) or suitably large samples from the later Epipaleolithic occupations at Öküzini 2 (16,000–15,300 cal B.C.) and Öküzini 3 (16,000–15,300 cal B.C.).

Caprines can live 10 y or longer in the wild and in captivity, yet the AH upper Level 4 assemblage is poorer than expected in older adults, especially 4–6 y olds (Fig. 5*B*). Interpretation of the mortality data are complicated by the strong likelihood that caprines were being harvested both from wild and captive populations. The juvenile culling pattern is explained largely by management, but the adult distribution almost certainly represents a mixture of managed and wild sources. Although Epipaleolithic assemblages are not poor in adult prey as a rule, some Mediterranean cases are exceptionally poor in older adults, such as in Karain and Öküzini (33) and certain other Epipaleolithic cases in the Mediterranean Basin (40). These cases may reflect situations in which heavy hunting squeezed wild-prey populations into a perpetual growth mode (40). This information is not enough to isolate incipient management practices.

Sex-Biased Harvesting. One of the most important zooarchaeological tests for animal management is sex-biased culling (21, 41,

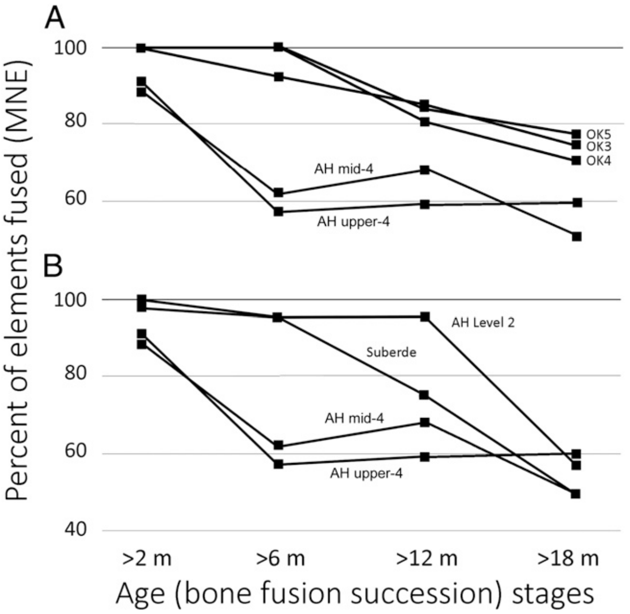

Fig. 4. Comparison of the AH caprine early stages of survivorship in months based on fusion data for assemblages from uppermost Level 4 (MNE = 207) and mid-upper Level 4 (n = 90) to (A) Epipaleolithic sheep-dominated caprine assemblages from Öküzini 3–5 (n = 354, n = 120, n = 124, respectively); and (B) to later PPN caprine assemblages from Level 2 of AH (n = 2,806) and Suberde (n = 95). Unborn individuals from AH are excluded from the comparisons. Sources of comparison data can be found in refs. 16, 33, and 34.

42). Here we target the pelvis because it is well represented in the AH faunas of upper Level 4, fuses early (approximately, 6–7 mo), and the sex of the animal usually can be determined from the structure of the pubic-acetabulum region, regardless of whether it has fused. Fusion and sex determinations for 52 caprine innominates indicate that only 11% of females died before the age of 6–7 mo, whereas 58% of males died before this age (Fisher's exact test, P = 0.0004). The age-sex bias in the caprines poses a strong contrast to hunting patterns for various ungulate species during the Upper and Epipaleolithic in the Near East and southern Europe (40). Returning to the fusion-based survivorship results in Fig. 4, the first interval of high mortality must relate to preferential culling of young males. Most females and a subset of the males lived beyond this age, although few if any of them enjoyed a long adult life. The pattern of sex-biased culling distinguishes the upper Level 4 AH caprines from the Epipaleolithic comparators. Instead, this pattern allies with early PPN comparators classified by Helmer et al. (37) as "Meat-focused Type A" culling. If milk exploitation occurred, such as from goats (the minority caprine at AH), this view of the data is not yet sufficient to expose it.

Geoarchaeological Evidence for Stabling. A critical geoarchaeological signature of ungulate management is in situ or primary dung deposits (*sensu* stabling) within the confines of a settlement. Ungulate dung may enter a Neolithic site as material collected by humans from the surrounding landscape for use as fuel and construction material or via on-site defecation by captive animals. The AH people did use dung as temper in mudbricks and as a binding agent for mortar and mud plasters. They also used dung in their fireplaces. These uses are not sufficient, however, to explain the volumes and distributions of dung residues among the buildings in upper Level 4 or in the overlying deposits.

There is also considerable, diagnostic variation in the character of the dung residues. Stabling deposits, or primary dung accumulations, are distinguished in the field by visible laminations and a striking orange sediment color (Fig. S3). Stabling deposits are confirmed in the laboratory from their microscopic characteristics (43, 44), including the presence of abundant calcareous spherulites interbedded with siliceous phytoliths, along with lesser amounts of secondary phosphorus and calcium oxalate crystals. A well-developed microlaminated undulating structure is also typical of intact remnants of stabling deposits (45). Such deposits have been identified in upper Level 4 as well in later occupations of the mound, both within the midden areas and in some outdoor spaces where other types of activities, such as knapping and butchery, were also conducted periodically (Table S8).

Phytoliths provide corroborating evidence of significant dung inputs and contents in upper Level 4. Phytolith remains from deposits that were identified as dung based on micromorphology are attributable to dicot plants, wild grasses, cereals, riverine sedges, rushes, and reeds. Among this diverse range of plant taxa, wild grass phytoliths occur in the largest quantities by far. Some of the wild grass remains in the site more generally may

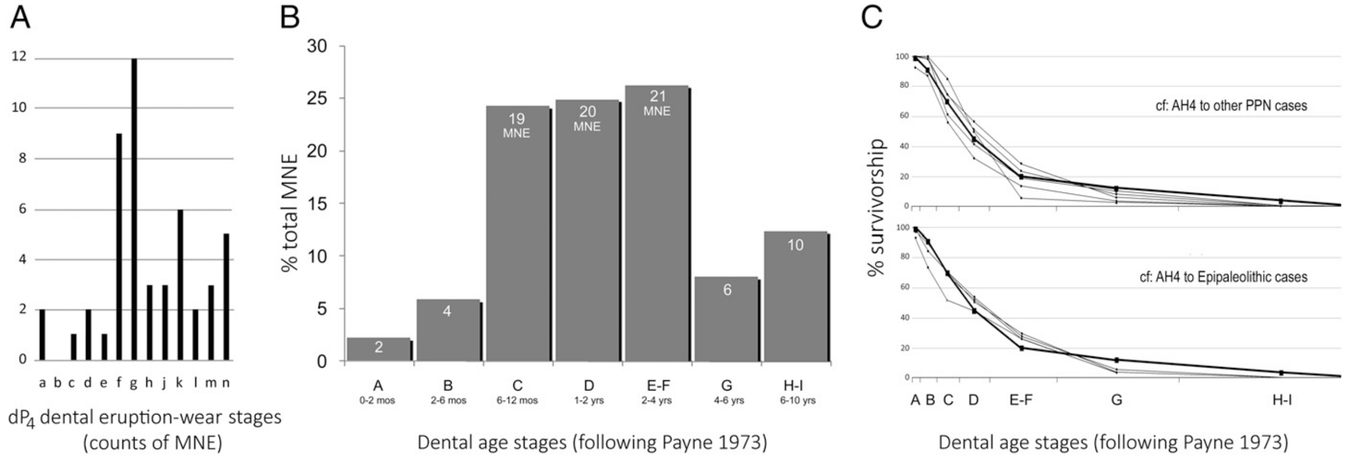

Fig. 5. AH upper Level 4 caprine age structure based on dental eruption-wear stages: (A) detailed juvenile mortality distribution based on counts of dP_4 milk teeth according to Grant's (36) sequential stages; (B) percentage MNE across Payne's (35) age stages for the total lifespan; (C) comparison of AH caprine survivorship (n = 82) to other PPN caprine assemblages from Göbekli Tepe (n = 48), Cafer Höyük (early phase, n = 21; midphase, n = 176), Tell Aswad (n = 97), and Tell Halula (n = 133), and to Epipaleolithic caprines from Karain B 1 and 2 (n = 93, n = 46) and Öküzini 2 and 3 (n = 85, n = 40). Sources of comparison data can be found in refs. 16 and 37–39.

represent food processing debris, but the majority of the grass phytoliths were introduced into the site as animal dung. The clear dominance of grass over dicot leaf phytoliths in the ruminant dung is consistent, moreover, with that produced by grazers (sheep or cattle) rather than browsing goats (46).

Concluding Remarks

The faunal and geoarchaeological evidence suggest a rapidly evolving predator–prey relationship at AH. A meat diet consisting of diverse ungulate and small prey species in upper Level 4 shifted smoothly over just a few centuries to one that overwhelmingly emphasized caprines. Human–caprine interactions in upper Level 4 were neither classically Epipaleolithic nor classically PPN in habit. Disproportionate culling of young males indicates deliberate manipulation of caprine survivorship by humans by or before 8200 cal B.C. Young caprines were killed throughout the year, but harvesting of juveniles rose sharply as winter approached and continued at moderate levels thereafter. Unfortunately, any interpretation of adult mortality in the caprines is complicated by the likely mixing of managed and hunted caprines in the archaeofaunas. Only the early mortality peak in the caprine assemblage, which is mostly composed of young males, clearly signals management by humans.

The distinctive caprine age-sex structures in upper Level 4 associate with primary dung deposits inside the settlement. More work is needed to understand the full scope and contexts of dung inputs in this level, but it is clear that ruminants were held captive between the buildings and occasionally in some of the work areas. The dung was produced foremost by grazing rather than browsing ungulates, and the zooarchaeological and phytolith evidence narrow the candidate species primarily to sheep. The caprines of upper Level 4 certainly were not domesticated (they retained wild morphology), but there is no doubt that small captive populations were being manipulated selectively by humans.

The gradual shift in species importance from upper Level 4 through Levels 3 and 2 suggests a local evolution of caprine management in this Central Anatolian site. The management methods appear primitive in that they were oriented to returns over shorter intervals than is typical in other PPN systems (37), including the methods of the AH Level 2 occupants. The Level 4 folk may have culled fattened young caprines very heavily in late autumn and early winter because they did not want to risk overwintering them when food supplies would be limited, risks of loss high, and foddering necessary. Even if this early system was relatively inefficient or unstable by later standards, considerable productivity could still be gained from captive juvenile and young adult stock. Sheep and goats depend on their mothers until 10 mo of age, but females can reach reproductive maturity as early as 18 mo, bearing their first young at 2 y. The goals of management during the occupations of upper Level 4 were geared principally or exclusively to meat production and multimonth (rather than long-term) live storage (37). The wide developmental spread of fetal-neonate losses seems to underscore the high risk and loosely experimental nature of early attempts at caprine management at AH. The fact that about one-third of all infantile caprine specimens are from fetuses could reflect indiscriminant culling of young pregnant females or spontaneously aborted lambs. Either way, the pattern implies a steep learning curve in the early evolution of management practices.

What sort of conceptual background was cradle to these innovations? In some regards, animal management was not a radical departure from complex strategies of the Epipaleolithic. Foragers of the earlier period frequently insulated themselves from risk and unpredictable food supplies by broadening the diet and by intensifying their use of certain resources. Both strategy sets generally entailed more work, and new kinds of work and social contracts, for some members of the group, but they are excellent solutions to reduced mobility from any cause. Intensification is largely a matter of squeezing more benefits out of every food package or patch that consumers could reliably control. Storage, grease rendering, and processing rich seeds and nuts are all examples of intensifying strategies. Diversification and intensification are two sides of the same coin: each is a common response to constrained food supplies or loss of mobility, and they often co-occur in complex hunter-gatherers (47). The strategic balance between the two modes tilted more toward intensified exploitation of core plant and animal species with the early Neolithic, at the expense of a diversified meat diet. The challenge for archaeologists is to better understand why such state shifts occurred.

One of the more striking energetic outcomes of the evolving predator–prey relationship at AH was the resurgence of large prey as the principle meat source. Taken at face value, this departure from an Epipaleolithic background of broad-spectrum hunting would seem a major reversal in humans' place in the local food web. However, the ratio of meat to plant energy sources in the early PPN diet may not have increased at all. Indeed the opposite is generally indicated by the many demographic pulses of the Neolithic (48), implying further "downward" shifts in humans' position in the food web as cereals and pulses became the main sources of carbohydrates. Groundstone artifacts and remains of cereal grasses, pulses, hackberry, nuts, and other seeds are widespread in upper AH Level 4 and testify to their great economic importance. Whatever humans' larger motives for manipulating caprine subpopulations, the changes in exploitation at AH were geared to maintaining ever-more reliable access to this meat source.

Caprine management at AH may not have been about creating a better prey animal but rather individual human solutions to an impending "tragedy of the commons" (49). The location of AH on the Melendiz floodplain and the rich botanical record suggest a heavy commitment to plant cultivation with the founding of the community. Permanent settlement on the floodplain would have led to local depression of meat sources, irrespective of whether climate was benevolent or harsh. Hunters might respond by searching farther afield, but not without incurring significant travel costs and time away from gardens and family. Sedentism, reduced prey encounter rates, and scheduling conflicts between long-distance hunting and plant cultivation may have induced AH residents to innovate rapidly to accommodate the latter.

One early pathway to stock-keeping could have been the timeless hunter-gatherer habit of bringing home young animals as pets. Ethnographic sources show, however, that such pets seldom survive for long because of neglect, abuse, or becoming yet another meal. At AH, a significant number of the captive sheep and goats lived many months, until their "stored" meat value could be realized. Another pathway to stock-keeping with much stronger incentives for care and vigilance comes from Epipaleolithic traditions of food storage and plant tending. If reasonably well cared for, captive animals are a means for both growing and live-storing meat and fat. The food transport costs are reduced because the animals are not hunted in remote places. Feeding herbivorous animals is work that must be done instead, but such work would already be supported by or embedded within the historical precedent of plant cultivation. Incipient animal tending might be especially viable for communities located on the edge—neither within or very remote to—highland hunting grounds. Failed experiments could be restarted or enriched on occasion by new expeditions into remote areas (see ref. 50 for related discussions). Sequestered live storage meanwhile would have reduced losses to competitors (leopards, wolves, and other people) and deflected the need for quick consumption.

If sequestered live storage improved meat security at AH, it must also have introduced new social strains. Some of the meat no longer came from a wild, common pool. Meanwhile the per capita consumption of meat may have gradually reduced as the caloric contributions of plant seeds overtook other foods. Keeping animals required new kinds of work and spatial accommodations. These developments surely had consequences for individual and cooperative labor over the long run, and for the social institutions that bind community members and affect their access to critical resources.

The trajectory of change at AH roughly parallels trends observed in certain other regions of the Middle East. Selective manipulation of caprines or pigs is evidenced at sites in the upper Euphrates region by 8500–8400 cal B.C., including Nevali Çori, Cafer Höyük, and probably Çayönü (11, 16, 38, 51), and on the island of Cyprus (20). As radiocarbon-dating efforts continue at AH, the bulk of the Level 4 sequence will likely fall across this temporal range, confirming AH's place in a larger web of socioeconomic and ideological innovations. AH is but one of several emergent cases of low-level stock production. Taken together, these cases demonstrate the futility of looking for a single point of origin in animal domestication. Experiments were geographically widespread, highly variable, and couched within a continuing tradition of hunting practices (11, 20).

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Supporting Information

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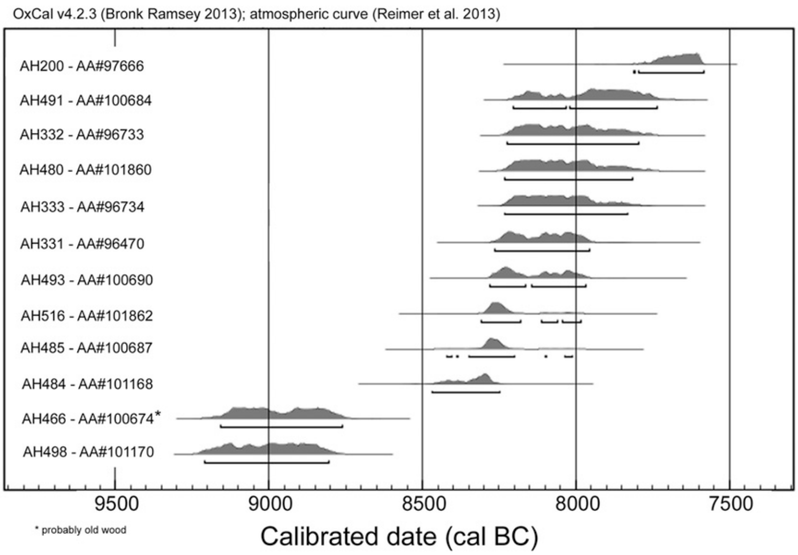

Fig. S1. Plot of radiocarbon results (cal B.C.) from combustion and other short-lived features in upper Level 4 of Aşıklı Höyük (AH) [OxCal v4.2.3 (1, 2)]. Note that most determinations are for the uppermost part of Level 4 in Trench 4GH on the north side of the mound, whereas the oldest determination (AA# 101170, from provisionally named Level 5) is for a sample obtained near the base of the mound in Trench 2J on the western slope. Brackets below each distribution (|_____|) signify 95% confidence interval.

1. Bronk Ramsey C (2009) Bayesian analysis of radiocarbon dates. *Radiocarbon* 51(1):337–360.
2. Reimer PJ, et al. (2013) IntCal13 and Marine13 radiocarbon age calibration curves 0-50,000 years cal BP. *Radiocarbon* 55(4):1869–1887.

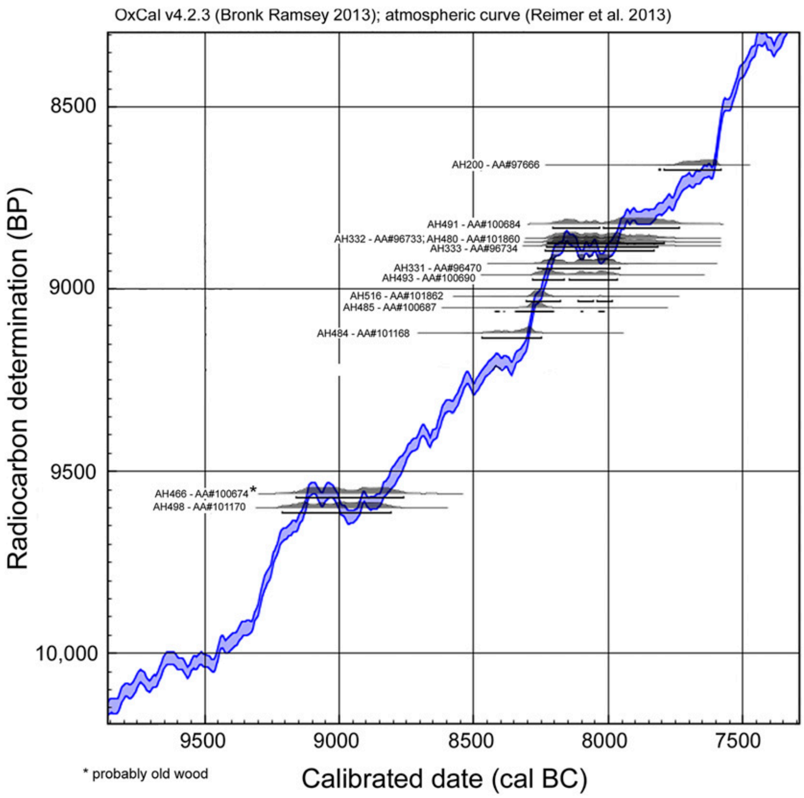

Fig. S2. Radiocarbon results from combustion and other short-lived features within Level 4 of AH plotted on OxCal v4.2.3 calibration curve (1, 2). Note that most of the currently available determinations are for uppermost Level 4 in Trench 4GH, whereas the oldest determination (AA# 101170) is for a sample obtained near the base of the mound on the western slope (Trench 2J).

1. Bronk Ramsey C (2009) Bayesian analysis of radiocarbon dates. *Radiocarbon* 51(1):337–360.
2. Reimer PJ, et al. (2013) IntCal13 and Marine13 radiocarbon age calibration curves 0-50,000 years cal BP. *Radiocarbon* 55(4):1869–1887.

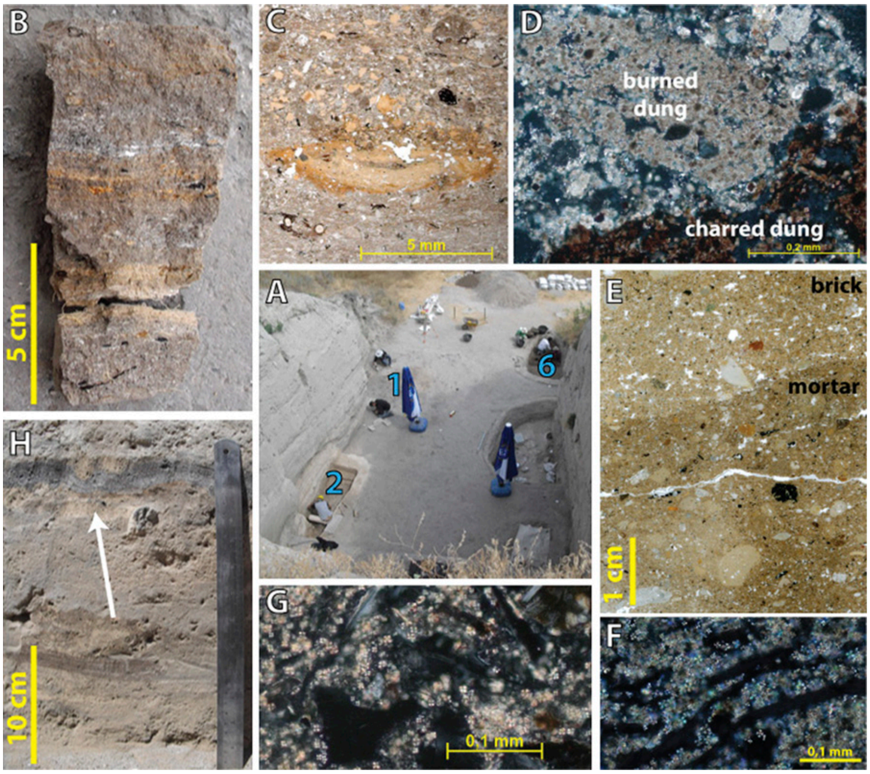

Fig. S3. Geoarchaeological evidence of primary dung deposits and secondary uses of dung in upper Level 4. (*A*) View of the Deep Trench (4GH) on the northern end of the mound, with excavators uncovering several open spaces and structures within upper Level 4. The locations of different types of dung deposits are indicated by architectural feature numbers. Space 1 contains intact layers of dung, and is underlain by spaces 7 and 13, which also contain sporadic but intact dung. Building 6 contains burned dung within its hearth and occupation deposits. Dung is also present in the mortar of the building's walls. Building 2 contains an intact layer of dung located above a floor. (*B*) Detail of dung layers in a micromorphology block collected from just above space 1. The dung appears orange and fibrous in the field, with numerous visible phytoliths. Field analyses of these types of layers include observations of color, reaction to acid, and smear slide production. Smear slides of dung deposits such as this one contain abundant phytoliths and spherulites. (*C*) Photomicrograph of the sample in *B*. Concentrations of yellow-orange secondary phosphate minerals are visible. These minerals form as a result of decomposition of the dung and contribute to the orange color that is visible in the field. Plane-polarized light. (*D*) Photomicrograph of burned and charred dung from the hearth in Building 6. When dung is burned under reducing conditions, the optical properties of the spherulites become altered. The dung was used as fuel within the structure, as evidenced by its presence within the hearth, as well as within generalized occupation debris. Cross-polarized light. (*E*) Incident light scan of a sample of brick and mortar from Building 6. The mortar was produced from anthropogenic refuse and contains aggregates of construction materials, ashes, fragments of charcoal, hackberry seeds, and dung (burned and not burned). (*F*) Intact dung from the upper Level 4 midden (location not visible in *A*). Intact dung is evidenced by interbedded phytoliths (here, black areas) and spherulites (light areas) with an overall undulating and laminated fabric (1). Relative to the dung in *C*, this dung is less affected by postdepositional decomposition, as evidenced by lower abundance of secondary phosphates and preservation of calcium oxalate crystals. Cross-polarized light. (*G*) Photomicrograph of a dense dung layer within Building 2. The light areas are concentrations of dung spherulites. The presence of only localized undulating laminated fabric indicates that this deposit may be in secondary position, or reworked in place. Cross-polarized light. (*H*) The dung layer from *G* located above a series of plaster floors in Building 2. The dung (arrow) is overlain by a deposit containing charred plant fibers and phytoliths.

1. Shahack-Gross R, Finkelstein I (2008) Subsistence practices in an arid environment: A geoarchaeological investigation in an Iron Age site, the Negev Highlands, Israel. *J Archaeol Sci* 35(4):965–982.

Table S1. Recently obtained radiocarbon results on burnt plant materials from discrete short-lived (mainly combustion) features in AH in Trenches 4GH (deep sounding in the northern area of the mound) and 2J on the western slope

UA Laboratory AA no.	AH project sample no.	Trench	Unit	Feature	Space	Building	Context description	Level	Elevation	Material	Context type	^{14}C yrs	±	cal B.P.	cal B.C.	±	2 σ	Range
AA101180	509	2J	570	371	138	17	Hearth	2/3	8.49	Charcoal	Hearth	8860	50	9970	8020	210	10,172	9,760
AA101182	511	2J	550	331	—	—	Fire installation	3	8.84	Charcoal	Combustion feature	8830	50	9930	7980	230	10,156	9,698
AA101183	512	2J	550	331	—	—	Fire installation	3	8.84	Charcoal	Combustion feature	8790	50	9870	7920	270	10,135	9,601
AA100674	466	2J	551	332	128	18	Reed floor	3	9.01	Burned roof timber*	Burned layer	9560	60	10920	8970	220	11,136	10,701
AA101178	507	2J	587	372	134	18	Hearth	3	9.91	Hearth charcoal	Hearth	8710	50	9690	7740	140	9,824	9,546
AA101177	506	2J	598	—	—	—	Hearth	3	10.14	Hearth charcoal	Hearth	9010	50	10090	8140	160	10,249	9,929
AA101172	501	2J	584	—	—	—	West profile, major burn layer	3	10.31	Charcoal	Burned layer	8900	50	10050	8040	160	10,196	9,886
AA101173	502	2J	584	—	—	—	West profile, major burn layer	3	10.31	Burnt dung	Burned layer	8870	50	9980	8030	210	10,179	9,766
AA101176	505	2J	598	—	—	—	Hearth	3	10.31	Hearth charcoal	Bearth	8900	50	10050	8100	160	10,196	9,886
AA101181	510	2J	585	366	136	20	Hearth	3	10.8	Hearth charcoal	Hearth	8720	50	9690	7740	140	9,834	9,550
AA101170	498	2J	584	—	—	—	West profile, major burn layer	base[†]	11.67	Charcoal	Burned layer	9600	50	10960	9010	200	11,160	10,756
AA100684	491	4GH	249	—	—	—	South wall, burnt dung	3/4	8.52	Burnt dung	Burned layer	8820	50	9930	7980	240	10,156	9,686
AA100690	493	4GH	255	84	15	1	Burial 131	4	10.73	Charcoal	Burial	8960	50	10080	8130	160	10,228	9,916
AA97666	200	4GH	105	32	5	3	Fire installation	4	11.19	Seed	Combustion feature	8660	50	9640	7690	110	9,532	9,744
AA96733	332	4GH	154	51	2	—	Fire installation	4	11.35	Charcoal residue	Combustion feature	8860	50	9970	8020	210	9,760	10,172
AA100687	485	4GH	227	73	2	—	Fire installation	4	11.46	Hearth charcoal	Combustion feature	9050	50	10220	8270	70	10,297	10,151
AA101862	516	4GH	227	73	2	—	Fire installation	4	11.46	Charcoal	Combustion feature	9020	50	10090	8140	160	10,254	9,933
AA101168	484	4GH	251	—	—	—	N of space 13, burnt phyto area	4	11.69	Charcoal	Burned layer	9120	50	10310	8360	110	10,416	10,197
AA101860	480	4GH	157	53	6	6	Base of Building 6	4	12.39	Burnt layer	Build-fill-base	8870	50	10370	8420	130	10,493	10,238
AA96734	333	4GH	149	49	6	6	Hearth	4	12.51	Charcoal	Hearth	8880	50	10020	8070	160	10,182	9,856
AA96470	331	4GH	149	49	6	6	Hearth	4	12.52	Charcoal residue	Hearth	8930	50	10070	8120	160	10,216	9,905

Results include samples from the lower part of Level 2, selected locations in Level 3 and uppermost Level 4 (key information color-highlighted), and one collected near the base of the mound on the western slope (Trench 2J).

*Early date in this instance probably reflects old wood problem.

[†] Sample taken from feature near base of cultural stratigraphy on the western side of the mound; this deposit is provisionally named Level 5.

Table S2. Relative abundance (number of identified skeletal specimens, NISP) of major taxonomic groups by level and level subsection in AH

Taxon	2A	2B	2C	2D	2E	2F	2G	2H	2I	2J	3A	3B	3C	3E	4a-4c	4d	4e
Toads/frogs (Anura)	—	6	12	3	—	—	—	1	1	5	8	6	—	8	89	78	96
Mice/voles (Rodentia)	—	37	—	9	—	—	—	1	15	40	90	5	—	—	178	38	24
Carp (Pisces)	—	5	2	36	4	—	—	—	62	513	346	30	216	44	886	429	377
Hedgehog (*Erinaceus*)	—	—	—	—	—	—	—	—	—	—	—	—	3	—	56	56	51
Tortoises/turtles (Chelonians)	—	4	2	7	4	5	1	3	—	14	2	1	10	1	163	105	165
Hare (*Lepus capensis*)	3	34	259	146	147	115	49	54	6	558	50	7	339	62	1,717	899	1507
Birds (Aves)	1	5	17	10	16	13	2	11	—	9	4	—	2	—	66	46	64
Horse/wild ass (Equidae)	3	31	67	45	16	86	44	28	10	370	12	16	38	10	139	114	180
Deer (3 species, Cervidae)	7	24	66	32	20	70	39	11	2	539	6	3	28	15	67	40	96
Aurochs (*Bos primigenius*)	139	219	689	364	175	411	217	123	27	1,961	123	23	30	13	306	212	823
Pig (*Sus scrofa*)	13	18	40	78	53	177	128	46	6	372	20	7	70	14	168	138	260
Goat (*Capra aegagrus*)	172	171	295	209	111	320	193	52	5	253	19	3	17	4	128	133	55
Sheep/goat (Caprini)	1,286	1,990	4,743	4,470	1,311	4,397	1,770	412	104	11,104	431	132	898	168	2,909	1,706	1,576
Sheep (*Ovis orientalis*)	381	501	1,328	1,118	434	1,450	937	260	29	1,460	135	30	45	51	414	254	176
Carnivores (Carnivores)	—	8	14	35	20	42	12	7	1	68	5	—	36	3	224	181	197
Total NISP	2,005	3,053	7,534	6,562	2,311	7,086	3,392	1,009	268	17,266	1,251	263	1,732	393	7,510	4,429	5,647

Note that Level 4a-d corresponds to the upper part of the Level 4, and 4e represents the upper-middle part of Level 4. Data are for faunal samples excavated through the 2013 field season.

Table S3. Summary of fusion states of tibias and metapodials by ungulate taxon

Taxon	% Juveniles	% Adults	Element-end (MNE)
Equidae	40	60	Distal tibia (10)
Bos	53	47	Distal tibia (19)
Caprines*	69	31	Distal metapodials (71)
Sus	26	74	Distal metapodials (22)

Percentages of juvenile (including infants) versus adults by ungulate taxonomic group in upper Level 4, based on limb bone fusion at or near the time of the deciduous-permanent premolar replacement boundary. MNE, minimum number of elements.

*Caprine limb fusion estimate excludes fetal bones.

Table S4. Raw and percentage data for caprine bone fusion by element and element-portion from the uppermost and mid-upper parts of Level 4, with very young (fetus and neonate combined) specimens listed separately

Element-portion	MNE fused	MNE unfused	MNE fetus-neon	total MNE	% MNE fused	%MNE unfused	%MNE fetus-neon	Sample source from within Level 4
Phalanx 1 – proximal	55	34	4	93	59	37	4	Uppermost
Innominate – acetilium	28	14	7	49	57	29	14	Uppermost
Tibia – distal	39	23	3	65	60	35	5	Uppermost
Metapodial – distal	15	27	11	53	28	51	21	Uppermost
Calcaneum – tuber calc.	21	33	1	55	38	60	2	Uppermost
Femur – proximal	9	26	8	43	21	60	19	Uppermost
Tibia – proximal	12	24	3	39	31	61	8	Uppermost
Radius – distal	13	24	6	43	30	56	14	Uppermost
Phalanx 1 – proximal	28	12	1	41	68	29	3	Mid-upper
Innominate – acetilium	13	5	3	21	62	24	14	Mid-upper
Tibia – distal	14	13	1	28	50	46	4	Mid-upper
Metapodial – distal	7	14	2	23	30	61	9	Mid-upper
Calcaneum – tuber calc.	4	17	0	21	19	81	0	Mid-upper
Femur – proximal	4	6	1	11	36	55	9	Mid-upper
Tibia – proximal	6	11	1	18	33	61	6	Mid-upper
Radius – distal	7	16	3	26	27	62	11	Mid-upper

Percentages of juveniles (including infants) versus adults by ungulate taxonomic group in upper Level 4, based on limb bone fusion at or near the time of the deciduous-permanent premolar replacement boundary.

Table S5. Analysis of the distributions of fetal versus neonate specimens by ungulate taxon in upper Level 4

Taxon	NISP fetus	NISP neonate	NISP (undetermined) fetus or neonate	*N*	*P**	*P*†
Equidae	0	10	2	12	0.144	0.021
Bos	0	18	3	21	0.034	0.001
Caprines	30	64	107			
Sus	0	22	4	26	0.015	<0.001
Cervidae	0	0	0			

N, hypothetical sample of size; $P^* = (1 - 0.149)^N$ or $(0.851)^N$; $P^\dagger = (1 - 0.319)^N$ or $(0.681)^N$. Neonate specimens were distinguished whenever possible from fetal specimens based on known age reference skeletons. Among the caprines from the upper part of Level 4, there are 201 bones attributable to either fetal or neonate individuals. Of these, definitively fetal bones constitute 14.93% (n = 30). Of the remainder, 64 (31.8%) are clearly neonates, and for another 107 very young specimens (53.2%) it is impossible to determine whether they are neonate or fetal. There are no unambiguous fetal bones found in the assemblage for any of the other taxa. Because we cannot use a χ^2 to evaluate differences among them as a result of the large number of empty cells in the data, we instead turn to simple probabilities. The question is whether the absence of fetal bones for Equids, *Bos*, and *Sus* demonstrate that they are sampling a different population of age groups than the caprines (the baseline for this comparison), or whether this could simply be an effect of smaller sample sizes. Assuming an actual frequency of fetal bones at 14.9% of the combined fetal+neonate sample, we can calculate the probability of selecting a hypothetical sample of size *N* in which there are no fetal bones. This is the same as 1 – (probablility of selecting only neonate or indeterminate bones). Note that there are neither fetal nor neonate bones for cervids, so no calculation is possible for this taxonomic group. The results presented above show that it is very unlikely that the absence of fetal bones in the samples of *Bos* and *Sus* is a result of sampling error alone. Because of the smaller number of Equid bones available for study, we cannot be certain that the absence of fetal specimens is not a sampling effect, although there is only a 14.4% chance that this is the explanation.

*Results for all three categories: fetus, neonate, and underdetermined fetus-neonate.

†Results for only two categories: fetus, neonate (excludes underdetermined fetus-neonate specimens.

Table S6. Dental-based age profile calculations and results for AH upper Level 4 caprines following Payne's (1) mandibular age stages (MNE = 82), and adjusted using the technique described by Helmer et al. (2) to include isolated tooth specimens

AH Level 4 Caprine dental age structure following Payne (1)	A (0–2 mo)	B (2–6 mo)	C (6–12 mo)	D (1–2 y)	E and F (2–4 y)	G (4–6 y)	H and I (6–10 y)
Raw counts (MNE)	2	3	13	16	0	0	0
Proportionally assigned	0	1.2	6.2	3.7	20.76	6.37	9.78
Corrected (raw+prop assign)	2	4.2	19.2	19.7	20.76	6.37	9.78
% total MNE	2	6	23	24	25	8	12

1. Payne S (1973) Kill-off patterns in sheep and goats: The mandibles from Asvan Kale. *Anatolian Studies* 23:281–303.
2. Helmer D, Gourichon L, Vila E (2007) The development of the exploitation of products from *Capra* and *Ovis* (meat, milk, and fleece) from the PPNB to the Early Bronze Age in the northern Near East (8700-9200 cal BP). *Anthropozoologica* 42(2):41–69.

Table S7. Data and Kolmogorov–Smirnov test results for comparisons of caprine survivorship based on dental results for upper Level 4 (all units combined) to Epipaleolithic (EPI) and other PPN cases from other sites

Site and component	Period	Source	*n* specimens	A	B	C	D	EF	G	HI	*D* value	df	0.05 Rejection threshold	*P*
Aşıklı Level 4	Early PPN	–	82	2	4	19	20	21	6	10	–	–	–	–
Göbekli Tepe*	PPNA	Peters et al. (1)	48	0	0	7	18	20	2	1	0.159	82, 48	0.247	>0.05
Cafer Höyük	Early PPNB	Helmer (2)	21	0	0	8	4	5	2	2	0.076	82, 21	0.333	>0.05
Cafer Höyük	Mid-PPNB	Helmer (2)	176	0	3	43	28	53	38	11	0.128	82, 176	0.182	>0.05
Aswad	Mid-PPNB	Helmer and Gourichon (3)	97	0	1	25	21	27	14	9	0.064	82, 97	0.204	>0.05
Tell Halula 5	Mid-PPNB	Sana Segui, in Helmer et al. (4)	133	9	12	39	30	25	14	4	0.146	82, 133	0.191	>0.05
Karain B 1	EPI	Atıcı 2009	93	0	16	11	18	21	25	2	0.100	93, 82	0.206	>0.05
Karain B 2	EPI	Atıcı 2009	46	0	4	11	7	12	11	1	0.100	46, 82	0.25	>0.05
Öküzini 2	EPI	Atıcı 2009	85	1	10	17	10	24	20	3	0.101	85, 82	0.211	>0.05
Öküzini 3	EPI	Atıcı 2009	40	2	9	8	3	7	10	1	0.201	40, 82	0.262	>0.05

*Values had to be estimated from published graphs, as primary data not given.

1. Peters J, Buitenhuis H, Grupe G, Schmidt K, Pöllath N (2013) *The Origins and Spread of Domestic Animals in Southwest Asia and Europe*, eds Colledge S, et al. (Left Coast Press, Walnut Creek, CA), pp 83–114.
2. Helmer D (2008) in *Archaeozoology of the Near East VIII: Proceedings of the 8th International Symposium on the Archaeozoology of Southwestern Asia and Adjacent Areas*, eds Vila E, et al. (Maison de l'Orient et de la Méditerranée, Lyon), pp 169–195.
3. Helmer D, Gourichon L (2008) in *Archaeozoology of the Near East VIII: Proceedings of the 8th International Symposium on the Archaeozoology of Southwestern Asia and Adjacent Areas*, eds Vila E, et al. (Maison de l'Orient et de la Méditerranée, Lyon), pp 120–151.
4. Helmer D, Gourichon L, Vila E (2007) The development of the exploitation of products from *Capra* and *Ovis* (meat, milk, and fleece) from the PPNB to the Early Bronze Age in the northern Near East (8700-9200 cal BP). *Anthropozoologica* 42(2):41–69.

Table S8. Micromorphology observations on 24 samples from Trench 4GH, collected from upper Level 4 during active excavations and from the contact between Levels 4 and 3 exposed in profiles from previous excavations

Architectural feature	Context	Level	No. samples	Intact dung?	Reworked dung?	Interpretation
Building 6	Hearth	4	1	No	Yes, abundant and burned (Fig. S3*D*)	Dung was used as fuel
Building 6	Mortar	4	1	No	Yes, low abundance (Fig. S3*E*)	Dung was incorporated into mortar with other anthropogenic refuse
Building 6	Occupation debris on top of floors	4	2	No	Yes, low abundance, burned and not burned	Dung was brought into the structure for use as fuel and was deposited on top of the floors along within other materials
Building 3	Mortar	4	1	No	Yes, low abundance	Dung was incorporated into mortar with other anthropogenic refuse
Building 3	Occupation debris and fill on top of floors	4	3	No	Yes, low abundance	Dung was brought into the structure for use as fuel and was deposited on top of the floors along within other materials; mortar containing dung became incorporated into fill
Building 2	Occupation debris and fill on top of floors	4	3	Localized (mm-scale)	Yes, high abundance in discrete layer (7–10 mm thick, Fig. S3 *G* and *H*), absent from generalized fill	Dung was used as a floor covering or surface within the structure; or dung was deposited as a result of stabling within the structure and became reworked in place
Building 2	Mortar	4	1	No	No	Dung was not incorporated into the mortar in this building
Spaces 1, 7, 13	Open space, activity areas	4	5	Yes, thin layers (mm-scale), variable degree of decomposition, interbedded with other materials	Yes, mixed into general anthropogenic debris	Spaces 1 and 7 were used extensively as work areas based on artifactual evidence; livestock periodically (briefly) were kept in the open spaces as well; space 13 mainly fill but patches of intact dung residues present
Space 1	Post mold	4	1	Yes, discrete layers filling a post mold	Yes, mixed into general anthropogenic debris	The open space was partially covered; upon removal of the post, livestock periodically were kept here
Above space 1	Open space, midden	4/3	1	Yes, multiple thick layers (totaling 7+ cm thickness, lateral extent of multiple meters, Fig. S3 *B* and *C*), highly decomposed	Yes, mixed into general anthropogenic debris interbedded with intact dung	Livestock were kept in this area; increase in abundance of animals or duration of penning relative to earlier phases (spaces 1–13)
Midden area	Open space, midden	4/3C	1	Yes, one thick layer (7 cm) (Fig. S3*F*), good preservation	No	Livestock were kept in this area
Midden area	Open space, midden	4/3C	1	No	Yes, burned and in layer containing charcoal, ashes and food debris; as clumps in other refuse, not burned	Dumping of hearth contents in the midden; use of dung as fuel; aggregates of dung in refuse
Midden area	Open space, midden	3E/3D	2	Yes, one burned layer (5 mm) containing charred plant fibers, phytoliths and spherulites, multiple layers, not burned (totaling 3+ cm)	Yes, burned and in layer containing charcoal, ashes and food debris	Use of midden area for keeping livestock, with occasional burning of the dung in place; dumping of hearth contents in the midden; use of dung as fuel

See Fig. S3 for criteria for the identification of intact dung, burned dung, and decomposition.