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Diet and nutrition in the Roman world – the contribution of zooarchaeology

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The role of animals in Roman diet and nutrition was multi-facetted and variable, posing a wide range of questions: what products were eaten of which types of animal, by whom and on what occasions? how were they prepared and distributed for consumption? in what relative and absolute quantities were they consumed and to what extent did they meet the cultural aspirations and nutritional needs of different demographic and social groups? Zooarchaeology, in the conventional sense of the study of animal remains – and especially the macroscopic study of durable skeletal remains – is a rich and essential tool for addressing such questions. Skeletal remains are available far more widely, not only temporally and geographically but also across different social groups, and are less subject to the promotion of idealised visions of consumption than the iconographic and written records on which work in this field was primarily dependent until recently. Moreover, with ongoing excavations and advances in macroscopic, microscopic and biomolecular analytical methods, the volume and resolution of skeletal data are increasing – and will continue to increase – much faster than the discovery of new images or texts. In common with images and texts, however, osteological evidence requires careful source criticism to realise its potential without falling foul of its limitations and ambiguities. Accordingly, the first section of this chapter outlines how the zooarchaeological record is formed and how zooarchaeologists extract meaning from it by ‘identification’ and recording of physical remains and then analysis and interpretation of recorded data. The second section then evaluates the potential of zooarchaeology to answer the questions listed above.

Zooarchaeological Formation Processes, Analysis and Interpretation

Two hypothetical examples, representing contrasting forms of animal consumption, may illustrate the nature of zooarchaeological formation processes and the potential and limitations of macroscopic study of skeletal remains. The first example concerns a sacrifice to a celestial deity in a newly constructed temple at a small, short-lived settlement of the late first century AD. Amid prayers and libations, a priest removes and burns a few hairs from a young all-white bull that is led uncomplaining to slaughter. The lifeless victim is opened up and inspection of its innards confirms that the ritual can safely proceed. The head and feet are removed for burial adjacent to the temple, the innards are burnt in offering to the deity, and the dressed carcass is butchered and cooked for a feast within the temple precinct attended by local dignitaries, each of whom receives a share befitting his status. After the diners discard bones stripped of meat, a few are scavenged by a pet dog, but most are collected for on-site burial in a second pit. Soon after, a catastrophic flood buries the temple under alluvium until modern ploughing turns up an inscription recording a dedicatory sacrifice. The resulting well-resourced research excavation practises intensive recovery, including systematic sieving of all clearly defined contexts.

The second hypothetical example focusses on a long-lived and densely inhabited town of the same date. With minimal ceremony, a butcher slaughters two elderly ewes from a local flock, delivering the skins with a few attached foot bones to a tanner. He sells the rest of the carcass as small joints to nearby households, where the larger limb bones are broken open before or after cooking to access marrow. Some bone fragments from meals are thrown with other domestic refuse into any open pits, but many are discarded in yards and streets, to undergo more or less severe attrition from gnawing, trampling, and weathering. Soon after, fire destroys the town, but it is rebuilt. During continued occupation over subsequent centuries, a medieval ditch obliterates the first-century butcher’s shop and tannery, while repeated cutting of pits and foundation trenches further scatters the sparse remains of our two sheep before eventual retrieval without sieving in rescue excavations preceding modern redevelopment.

The temple site’s zooarchaeologist examines bones from two pits close to the temple foundations. All are from large animals and those identifiable to species from cattle. A few specimens exhibit fresh breaks, inflicted during excavation, and an incomplete limb bone has traces of ancient gnawing. Otherwise, the more robust bones are intact and form matching left-right pairs and/or articulate smoothly with anatomically adjacent elements, showing that one pit contained the head and feet and the other the remainder of the same individual skeleton. In the mandible (lower jaw), permanent (adult) premolars are in the course of replacing their deciduous (‘milk’) precursors and the third molar at the back of the tooth row is just coming into wear, so the animal died at around three years old. Likewise the limb bone epiphyses (articular ends) expected to fuse to the diaphysis (shaft) at around three years of age are partly fused, while those expected to close at a younger or older age are fully fused or fully unfused, respectively. Preserved bone dimensions, especially sexually dimorphic forelimb breadth measurements, are larger than many fully adult specimens from contemporary sites nearby, suggesting a male animal. A deep axe or cleaver chop mark into a neck vertebra may have caused death, while similar blows had parted the vertebral column into sections. The limbs were dismembered by a smaller knife that left finer cut marks transversely around articulations, while the absence of longitudinal or diagonal cuts to shafts suggests that raw meat was not filleted from the bone (the carving of *cooked* meat, requiring less force, is less likely to leave traces). Meat was apparently roasted ‘on the bone’ as several dismembered specimens exhibit light burning on the exposed articular surfaces but not the protected shafts. Unusually, since most bones are unbroken, no attempt was made to retrieve bone marrow or grease, while the lack of cuts on the intact skull or mandible suggests that meat from the head, including tongue and brain, was discarded. Lack of gnawing implies rapid burial of the head and feet, while the rest of the carcass, although discarded within reach of dog(s) that damaged a few bones and perhaps destroyed or removed a few missing specimens, was subsequently gathered up and buried. The wasteful consumption and careful disposal of a large and prime-aged animal implies a significant commensal episode, which context suggests was probably preceded by sacrifice – although the associated rituals are osteologically invisible (cf. King, 2005).

The urban site has yielded more challenging material of variable date from several modern construction sites, although a widespread conflagration sealed, and therefore identifies as broadly contemporary, a series of late first-century AD surfaces and fills. The overwhelmingly fragmentary bones in these deposits are mainly of sheep/goat (of which all those identifiable to species are sheep), pigs and cattle. The representation of body parts is very uneven and differs between these three taxa, but ease of identification and likelihood of recovery and survival also vary significantly and must be considered before claiming selective treatment of carcass parts or species by Roman butchers and consumers.

Working backwards through potential biases, in a heavily fragmented assemblage some body parts especially (e.g., the more robust ‘long’ limb bones of cattle) yield multiple, durable and identifiable pieces and so are overrepresented by total numbers of identified specimens (NISP). Accordingly, the zooarchaeologist has recorded presence or absence of ‘diagnostic zones’ within body parts, to estimate the minimum numbers of bones represented. Next, excavation without sieving tends to miss small body parts, such as phalanges (toes) and tarsals (ankle bones) especially of smaller species. Here pig and sheep phalanges and tarsals are very underrepresented, but not so the larger and anatomically intervening metatarsals (upper foot bones), suggesting that the tarsals at least were not discarded during slaughter and skinning, but missed during excavation. The phalanges and tarsals of cattle are much larger and only the former are underrepresented, probably removed elsewhere during primary butchery rather than lost during excavation; a later pit, outside a non-residential building, contained numerous unbroken cattle and sheep phalanges, perhaps removed with the hide and then discarded during hide working. Lastly, among the larger limb bones, the robust distal (lower) humerus is far more frequent than the fragile proximal (upper) part, suggesting that attrition by dogs (below) and perhaps trampling has significantly shaped the surviving assemblage.

Any remaining irregularities in assemblage composition may reflect ancient human choices. Whereas pig and sheep jaws are well represented and were probably distributed ‘on the bone’ with the rest of the dressed carcass, those of cattle are surprisingly scarce, suggesting discard of the heads elsewhere (perhaps stripped of edible matter by the butcher). Otherwise, with allowance for expected biases, body part representation is fairly even, with no evidence of differential access to meat-rich cuts between excavated neighbourhoods, although the larger houses yielded higher proportions of pig bones.

Traces of gnawing were frequent in pig, intermediate in sheep, and infrequent in cattle, whereas breakage with cleavers exhibited the opposite pattern. Moreover, among fragments preserving all or part of the articulation, younger (unfused) specimens were more often gnawed than chopped and older (fused) ones the reverse, even though the vulnerability of young specimens to attrition favours the opposite outcome. After primary butchery, therefore, the larger bones of cattle and adults were chopped up, for pot-sizing and/or to extract marrow and grease, whereas those of smaller species and younger individuals were often cooked intact and so were more attractive to dogs after discard. The extensive use of heavy cleavers and fairly standardised placement of cleaver marks, especially on cattle, suggest carcass processing by specialist butchers, rather than on a domestic scale. The lack of likely paired or articulating bones is also consistent with this interpretation, although heavy fragmentation and attrition greatly reduce the likelihood of recognising such matches.

As already hinted, the degree of epiphyseal fusion between limb bone articulations and shafts suggests that pigs were slaughtered young, sheep as a mixture of juveniles and adults, and cattle mainly as adults. The more precise evidence of dental eruption and wear confirms this picture for pigs and sheep, but suggests younger slaughter for cattle – perhaps because the ‘missing’ jaws (above) were mainly from adults. Biometric data (bone measurements) suggest slaughter of immature male and adult female sheep, but are uninformatively sparse for pigs (because of young deaths and frequent gnawing) and cattle (because of intensive chopping). The combined sex and mortality data imply that the pigs and many of the sheep consumed in the town were reared for meat, but that cattle were culled after working, breeding or being milked for several years. A few fragments from the proximal femur (hip) and distal metacarpal (fore-foot) of cattle exhibit degraded articular surfaces potentially attributable to ‘traction stress’ and thus compatible with use as draught animals.

These two ‘case studies’ share important common ground. First, zooarchaeological ‘identification’ includes a long list of variables related to depositional history (gnawing, weathering), preparation for consumption (cut marks, fragmentation) and husbandry (sex, age at death, biometry, pathology) as well as body part and taxon. Secondly, these variables are diagnosed by comparison with present-day specimens of known identity or history. Thirdly, the proportion of ‘identifiable’ specimens differs between variables: depositional history, body part, and taxon are determinable more frequently than variables relevant only to certain body parts (e.g. dental evidence for age, morphological evidence for sex) or relatively complete specimens (e.g., biometry). Fourthly, careful consideration of assemblage formation processes is a precondition of reliable insight into ancient consumption practices.

The case studies also exhibit strong contrasts. The temple assemblage comprises most parts of a single animal, for which butchery, consumption and discard history can be reconstructed in considerable detail. Conversely, in the urban assemblage, anything that has survived of our original two elderly ewes is irretrievably mixed with the scattered, fragmented and often poorly preserved remains of many animals. Based on the most abundant parts (durable distal humeri of cattle and mandibles of smaller taxa), the minimum number of individuals (MNI) represented in excavated deposits underlying the burnt destruction is about 100, but no plausible left-right pairs or articulating elements were observed, so each of the approximately 5000 identified and recorded specimens *could* be from a different individual. Even this figure, equivalent to only 100 animals slaughtered per year over the five decades during which the relevant deposits accumulated, may be a significant underestimate. The large size of this urban assemblage enables useful insights into how different species were butchered and their carcasses dispersed across the city, but these are aggregate patterns of multiple slaughter and consumption episodes over many years and in a variety of commensal contexts.

Unfortunately, while zooarchaeological material of benign formation processes and high contextual resolution is encountered, the hypothetical urban case (or worse) is much closer to the norm.

Questions about Diet and Nutrition: the Potential of Zooarchaeology

What can we reliably infer about diet and nutrition from zooarchaeological assemblages of variable formation history and contextual resolution? The questions posed at the beginning of this chapter are here addressed in ascending order of difficulty.

First, which types of animals were eaten? A few animals found on Roman habitation sites, often as more or less intact skeletons, may represent later intrusions (e.g., burrowing species and their prey) or commensals attracted by human stores or refuse (e.g., small rodents at York – O’Connor, 1988, 117), while others may have been exploited only for their pelts or discarded/buried intact as unfit to eat (e.g., dogs and horses at Ribchester fort, northwest England – Stallibrass, 2000). For the most part, however, Roman faunal assemblages overwhelmingly comprise disarticulated bones variously bearing knife or cleaver marks or localised burning traces and exhibiting fragmentation patterns or anatomical frequencies that in combination suggest the remains of carcasses processed for human consumption. On this basis, it seems clear that cattle, goats, pigs and sheep were routinely eaten, as also, albeit less clearly for reasons of smaller sample sizes, were chickens and a more or less broad range of wild species. The same was sometimes true for horse, donkey, mule and dog, although sparse butchery and fragmentation indicate much lower 'edibility' (e.g., Dobney et al., 1996, 46-47; Peters, 1998, 287; Lauwerier and Robeerst, 2001).

Secondly, which animal products were consumed? Butchery marks, bone breakage and localised burning may provide fairly direct evidence for removal or cooking of meat *sensu stricto* (flesh or muscle), tongue, brain, marrow and grease, but exploitation of offal (other than brain and tongue), blood and milk leaves no direct macroscopic osteological trace. The intestines, internal organs and blood from slaughtered animals, consumption of which is recorded in Roman literary sources, were traditionally used for culturally significant dishes in many regions of Europe, while bleeding of *live*stock in the recent past (e.g., in highland Scotland) could mitigate food scarcity. Milk products too were culturally significant in antiquity: written sources cite regional cheeses, used in elite cuisine, while drinking milk could be a sign of rustic backwardness. Milk is especially significant nutritionally, however, because milking of female domestic ruminants can potentially yield far more protein and energy than eating both them and their offspring (Legge, 1981, 89). Lipid traces in pots may identify the heating of milk (e.g., for Iron Age Britain – Copley et al., 2005), but not processing in organic containers nor probably consumption of fresh milk, while whey proteins preserved in human dental calculus may identify both individual consumers and the source species (Warinner et al., 2014). More indirectly, macroscopic zooarchaeology may reveal whether male domestic ruminants died in infancy and so consumed very little maternal milk or survived long enough potentially to compete for milk with humans (Payne, 1973; Legge, 1981). In the latter case, analysis of changing nitrogen isotope ratios during first molar development may reveal whether early weaning made milk more available to humans (Balasse and Tresset, 2002). Both mortality and weaning patterns measure dairying *potential*, but do not demonstrate milking (Halstead, 1998), so they complement ceramic and dental calculus evidence which document the practice but not its scale or intensity.

Thirdly, how were animal products prepared and distributed for consumption? Although blind to the use of milk, blood and most forms of offal, osteological traces of cutting, breakage and burning, coupled with more or less selective anatomical representation, may reveal interesting qualitative details of the processing and preparation for consumption of the rest of the carcass, including some striking differences between both species and depositional contexts. Carcass processing sequences (O'Connor, 1993) are clearest on urban settlements, where anatomically selective dumps, especially of cattle bones, are reasonably commonplace and widespread (Maltby, 1985, 52; Lignereux and Peters, 1996; Peters, 1998, 258-68; Lachiche and Deschler-Erb, 2007; Lepetz, 2007; De Cupere et al., 2015). Such dumps attest to the temporal and sometimes spatial segregation of primary butchery (heads and feet discarded) and hide- and horn-working (toes and horncores discarded), while consumption of dressed carcasses involved extensive filleting of meat for distribution off the bone, preserving (probably by smoking or brining) of shoulders perforated for hanging (sometimes distributed off the bone), and systematic chopping of long bones for production of marrow and broth and perhaps glue (Figure 1). Compared with rural sites and earlier periods, urban carcass processing used cleavers rather than knives and consistent time-efficient methods that, together with anatomically selective discard, imply specialist butchers working on a large scale (Seetah, 2006; Lachiche and Deschler-Erb, 2007; Lepetz, 2007; Maltby, 2007). Less consistent methods and anatomically less selective discard on rural sites may reflect household rather than specialist carcass processing, but are also reported for sheep(/goats) and pigs on urban sites, perhaps partly because smaller carcasses were more often (as today) distributed on rather than off the bone. Nonetheless, some anatomically selective deposits also reveal large-scale processing of pig carcasses, with preserved hams perhaps exported from Iron Age and Roman rural sites in France (Frémondeau et al., 2015) and England (Maltby, 2006). Table waste tends to be particularly elusive, because of piecemeal discard, but plausible examples include concentrations of fish or bird bones with ribs and vertebrae of pigs or sheep (all difficult for butcher or cook to strip of meat) at Roman Caerleon and York in southern Britain (O’Connor, 1993). Likewise, in an early Roman tavern at Lattes, southern France, the floor of the dining room yielded vertebrae, but the adjacent food-preparation area heads and scales, of fish (Luley and Piquès, 2016). The tavern also served meat of cattle and sheep, as well as bread and abundant drink, and a votive deposit in this otherwise secular setting included a millstone, plate, drinking bowl and cuts of meat. A stark contrast in scale and context of consumption is afforded by the sanctuary of Mercury atop the Puy de Dôme, central France, where simultaneous dumping of parts of at least 112 pigs apparently followed *in situ* butchery and cooking of the hams, but discard of intact lower limbs (Méniel, 2014) – ‘gourmet’ behaviour very different from parsimonious urban broth making.

Fourthly, by whom and on what occasions were animal products consumed? Particular occasions of consumption can sometimes be identified, for example at Great Chesterford temple, southern England, where rapidly buried mandibles and feet from accurately ageable first-year lambs suggested mass slaughter in spring and autumn (Figure 2); while most toes (presumably attached to skins) and meatier parts were removed, a few exclusively right-sided forelimbs, also deposited within the precinct, have plausibly been identified as the priest’s portion (Legge et al., 2000). Distinctions are apparent *within* sites between groups of consumers. At South Shields fort, northeast England, the fourth-century AD commandant’s house received proportionally more beef (especially meat-rich upper-limb cuts), chicken, goose, duck and hare than the third-century soldiers’ barracks, where more pork and especially mutton and all parts of cattle carcasses were consumed (Stokes, 2000). In the Rhineland villa at Bad Kreuznach, guests consumed a range of wild species rarely encountered in the domestic quarters (Peters, 1998, 249), while on a larger scale the higher-status central *insulae* of urban Augst, Switzerland, enjoyed better access to pork and poultry than did poorer outlying neighbourhoods (Schibler and Furger, 1988; cf. Furger, 1994). On a larger scale, differences are widely reported between regions, periods and site types in the relative abundance of the common domesticates. The consistency of some such trends is perhaps surprising, given the sometimes considerable differences between sites in the quality of bone preservation and types of depositional contexts (and hence perhaps pre-depositional activities) sampled, between excavations in recovery standards, and between zooarchaeological specialists in quantification protocols. These complicating factors, however, are far more likely to have obscured than created the observed regional, temporal and contextual trends in taxonomic composition. Thus, for Late Iron Age to Late Roman Britain, there is no reason to doubt a trend from sheep towards cattle and pigs that was more marked on military and urban than less ‘Romanised’ rural sites, although there is no consensus whether this represents adoption of Roman or at least continental culinary preferences (King, 1978; 1999) rather than practical corrollaries of increasing urbanism and trade (e.g., Albarella, 2007; Albarella et al., 2008).

Fifthly, in what relative quantities were animal products consumed? Despite some broadly consistent trends in species frequencies among recorded bones, converting these to frequencies among bones originally discarded is more problematic. Without intensive sieving, small anatomical parts of sheep, goats and pigs (and even more so of many bird and fish species) are almost inevitably underrepresented relative to those of cattle. In assemblages subject to significant canid attrition or trampling, bone survival is likely to be much poorer in species slaughtered young, as is common with pigs, than in those culled at a greater age, as cattle especially tend to be. The larger limb bones of cattle were often chopped into more numerous pieces than those of the smaller domesticates, potentially resulting in either over- or under-representation of the former, depending on how assiduously fragments are identified and how conservatively they are quantified. While the *direction* of such biases is quite predictable, however, appropriate correction factors are not easily defined (e.g., Maltby, 1985, 40-49; O’Connor, 1988, 75). Estimates of minimum numbers of individuals (MNI) generally dampen the effects of interspecific differences in survival, recovery and butchery, as well as controlling for differences in anatomical structure (e.g., variable numbers of foot bones in complete skeletons of different species), but exaggerate the abundance of rare species and may be very inaccurate if calculated from numbers of identified specimens (NISP) rather than estimated minimum numbers of body parts. Taking account of variables such as side of body, age and size, MNI is usually assessed from the best represented body part, which is often the mandible, and so may underestimate species with older age profiles (and thus less precisely ageable mandibles) and even more so any whose heads are discarded during primary butchery off-site.

To convert any quantified estimates of species composition into relative contribution to overall meat intake requires allowance for differences between species in carcass size. Ideally, this exercise should take account of age at death and sex ratio of each species and of biometric evidence for the size of local breeds (e.g., Vigne, 1991), but coarser approximations are more usual and perhaps more appropriate given the resolution of the underpinning zooarchaeological data. That meat weights are usually estimated for whole animals may also be problematic, given that part-carcasses (e.g., smoked shoulders – Deschler-Erb, 2013; Lachiche and Deschler-Erb, 2007) were sometimes introduced to particular sites or contexts. Potentially most problematic in using consumption debris to estimate different species' dietary importance is again the low zooarchaeological visibility of milking. While ceramic residues may confirm the use of milk and perhaps also its conversion to more storable cheese (e.g. Copley et al., 2005), our best guide to the intensity of milking is arguably the extent to which mortality patterns or isotopic weaning records suggest management maximising the *potential* for specialised dairying (Halstead, 2014). If (some) domestic ruminants were milked, therefore, butchered animal bones may offer an extremely incomplete picture of the contribution of different species to human diet, especially if consumption of milk tends to be more egalitarian than that of meat (Stegl and Baten, 2009). Yet more challenging, even disregarding the lower visibility of dairy than carcass products, is zooarchaeological assessment of the combined dietary contribution of animal foods, because the formation processes of bones and plant remains are so different that their quantified records cannot meaningfully be compared. Fortunately, much of the human population of the Roman world lived in urban aggregations sufficiently large that dietary dependence on staple grain crops seems inevitable, but for smaller rural communities, especially in upland regions, such dependence should be demonstrated rather than assumed.

Sixthly, in what absolute quantities were animal products consumed and to what extent did they meet the cultural expectations and nutritional needs of different demographic and social groups? Under favourable recovery, preservation and especially discard conditions, absolute quantities of carcass products prepared or consumed in particular events may be inferred from short-lived depositional episodes. Striking examples, albeit of meat ultimately ‘wasted’ are a pot filled with 28 thrush breasts at Nijmegen (Lauwerier, 1993a), the Lattes tavern votive deposit (above) and numerous grave offerings (e.g., Lauwerier, 1993b). Sanctuary deposits, such as at Puy de Dôme and Great Chesterford (above), are much larger-scale and probably reflect actual rather than symbolic consumption, although single depositions might include curated remains of multiple feasts. Given the multiple obstacles outlined above to even *relative* quantification, the difficulties of more generalised absolute quantification from zooarchaeological data are plain. Moreover, to assess the extent to which consumption meets cultural expectations or nutritional needs, it needs to be quantified per person and ideally for individuals of known age, gender, social standing, cultural identity and life history. This demands human skeletal analysis of isotopic and biometric proxies for dietary quality, the compatibility of which with zooarchaeological evidence requires comment. Nitrogen isotope ratios in human bone measure fairly directly, on the same basis as they detect weaning, animal protein (meat or dairy) intake, although values can be raised by consumption of manured cereal grain (or animals that have eaten manured cereals) and depressed by consumption of pulses. Osteological estimates of human stature have underpinned several recent studies of diachronic trends in nutritional quality in various regions of the Roman world (e.g., Koepke and Baten, 2008), but stature is a more indirect proxy measure of diet than is bone chemistry and may be heavily influenced by disease and thus hygiene (e.g., Hatton and Bray, 2010), in addition to possible regional differences in genetic potential. Perhaps most seriously, both isotopic and biometric evidence for changing dietary quality may be misleading if the funerary record over- or underrepresents social groups living under atypical conditions of diet, physical exertion, hygiene and so on. For example, at Gloucester**,** southern England, single and mass burials, plausibly attributable to individuals of higher and lower status respectively, exhibited contrasting nitrogen isotope ratios implying differences in protein intake (Cheung et al., 2012). It is highly improbable that the extant skeletal record includes a similar proportion of both burial/dietary groups and inevitable that remains of some groups – here or elsewhere – have not survived or been recovered at all. Moreover, human isotopic proxies are interpreted relative to local crop and livestock 'baselines', also subject to risks of unrepresentative sampling. Thus, any apparent contradictions between zooarchaeological and human skeletal evidence for consumption of animal products may offer valuable hints that the two data sets are sampling different social groups or different dimensions of consumption. For example, the human body absorbs (and isotope ratios thus reflect) frequent small intakes of animal protein far better than rare episodes of excess, whereas the zooarchaeological record is probably biased towards the latter – if only because remains from large-scale carcass processing are more likely to be buried rather than exposed to attrition on surfaces (e.g., Maltby, 1985, 60) while dogs favour fresh bone and hence piecemeal discard. Abundant evidence for butchered animals coupled with low nitrogen isotope ratios in human skeletons might, therefore, reflect meat consumption in rare events of ostentatious carnivory, while the converse might reflect consumption of animal protein primarily as dairy produce. In this case, while the isotopic evidence sheds most light on human health or dietary quality, the zooarchaeological record may be more revealing of the commensal politics of meat eating.

In closing, the difficulty of quantifying consumption of animal products is illustrated by consideration of Jongman's (2007a; 2007b) recent use of the macroscopic zooarchaeological record to measure living standards or economic performance in the Roman world. Jongman persuasively justifies meat consumption, as his preferred metric, in terms of the income elasticity of demand: 'we need to look at goods that are too expensive for the very poor, attractive and potentially affordable for those who lived somewhat above subsistence, but not something the very rich could consume in huge quantities. Meat is a suitable indicator of intermediate prosperity' (Jongman, 2007a, 613). From published syntheses, Jongman charts numbers of mammal bones deposited per century, as avowedly rough proxies for the scale of meat consumption, between the sixth century BC and the eighth century AD (Figure 3). In Italy, deposition rises and then falls over this period, with peaks in the first and fifth centuries AD separated by a trough in the third century AD, while in the provinces of the Roman Empire (overwhelmingly represented by assemblages from north of the Alps) heavy deposition is more narrowly restricted to the first century BC-fourth century AD period of Roman rule with a peak in the second century AD. Perhaps encouragingly for Jongman (but cf. Scheidel, 2009; Wilson, 2009), heavy deposition roughly matches other proxies (e.g., shipwrecks, lead pollution) that suggest a rise and fall in aggregate economic activity over the Late Republican-Imperial period (Jongman, 2014). Moreover, although bone deposition curves are a proxy for *aggregate* meat consumption, their match with a proposed late first-early second century AD peak in living standards, inferred from human femoral lengths (Jongman, 2007b, 194 fig. 7), is compatible with increased consumption *per caput*. Other scholars, using slightly different biometric protocols and perhaps skeletal samples, have in fact proposed a decrease in human stature at this time (Giannechini and Moggi-Cecchi, 2008), but the focus here is on the analytical and formation processes underpinning Jongman's *faunal* data.

First, total bone counts exaggerate changes in meat consumption in Italy, given a 'Roman' predeliction for small suckling piglets (King, 1999), and understate them elsewhere (especially Britain), where 'Romanisation' apparently involved increased frequencies of cattle. Conversely, as Jongman notes, allowance for the large size of some Roman livestock breeds would accentuate his suggested trends. In estimating meat consumption, therefore, bone counts should ideally be 'corrected' for species, breed and age, which is neither easy nor accurate, but also unlikely to neutralise or reverse his suggested trends. Secondly, identification and quantification protocols, retrieval standards, and excavation priorities have certainly varied, but are unlikely to correlate strongly with date of deposition. By default, the bone deposition data may be broadly representative of fluctuating numbers of surviving bones encountered in layers of different date. Thirdly, other things being equal, the likelihood of archaeologists finding deposits of a particular century should be roughly proportional to the number and extent of sites occupied and thus to human population size. In Italy, census records have been interpreted as indicating rising late Republican-early Imperial population, but only the steepest of the alternative suggested trends (Scheidel, 2007, 31 fig. 2) matches, and so potentially accounts for, the increased bone deposition. Fourthly, even given a constant rate of bone discard over time within an inhabited area, the rate of *in situ* bone survival is likely to be very uneven. For example, while bone on stable occupation surfaces is susceptible to attrition or removal for off-site discard, large-scale rebuilding may create extensive fill deposits that trap and preserve bone in large quantities. Jongman notes that public building projects in Italy peaked in late Republican-Early Imperial times, declining in the late second century AD before a temporary recovery (2007, 616), while dated wood remains from Germany indicate a marked pulse in construction activity in the first century BC to second century AD. Increasing population and the surge in building could alone account parsimoniously for the observed temporal trend in aggregate bone deposition without any change in *per caput* consumption. Any increase in human stature, if not an artefact of the geographical or social structure of the human skeletal sample, could be due to improved hygiene or consumption of protein on a more regular or egalitarian basis rather than in larger aggregate quantities. Choosing between these and other alternatives requires analysis of *multiple* proxy datasets.

Conclusion

Animal bones are far more ubiquitous, and also more amenable to quantitative analysis, than all other sources for Roman consumption of animal food resources. They are also much less likely to represent cultural ideals rather than routine practice, although structured deposits with a normative message are widely encountered. On the other hand, routine 'non-structured' refuse is perhaps less likely to be buried rapidly and so more likely to undergo severe attrition and mixing of by-products from diverse activities. Accordingly, all faunal deposits require careful 'source criticism' of the discard practices and survival conditions, as well as retrieval and analytical methods, that have shaped published data. The biases introduced by formation processes are often predictable in direction, but not in degree. Accordingly, zooarchaeology can rarely provide *absolute* quantification of, for example, meat consumption in a particular historical context, while even *relative* quantification of, say, the dietary contribution of different species must often be treated with caution. On the other hand, zooarchaeology can offer relative quantitative comparisons between periods, regions, site types, intra-site contexts and species and also a wealth of qualitative insights into animal carcass processing and consumption.

Integration with other classes of evidence greatly enhances the value of the macroscopic faunal data on which this chapter has focussed. For example, textual and iconographic sources reveal culturally important detail regarding the ritual and symbolism of sacrificial slaughter (e.g., Aldrete, 2014), but zooarchaeology clarifies the extent to which the Romans consumed 'profane' as well as 'sacred' meat (Scheid, 2012, 90; Lachiche and Deschler-Erb, 2007; Lepetz, 2007). Iconographic representations of butchery and slaughter, coupled with finds of the tools depicted and with experimental replication have shed rewarding light on the methods, traditions, aims and constraints of urban, rural, military and civilian carcass processing (Lignereux and Peters, 1996; Deschler-Erb, 2006; Seetah, 2006; Maltby, 2007; Monteix, 2007). Archaeological context is invaluable in disentangling the practical, social and symbolic dimensions of carcass processing and consumption, without making potentially circular assumptions about the cultural value of different species, ages and cuts of animals (Ervynck et al., 2003). For example, the second century AD communal dining structure at Sagalassos, Turkey, was identified as such primarily from the functionally restricted ceramic vessels in an adjacent dump, while poor-quality tableware attributes the associated faunal material to low-status dining (De Cupere et al., 2015, 191-95). Such high-resolution and closely contextualised zooarchaeological ‘windows into the past’ are now quite numerous, but – in terms of potential for quantification – are perhaps comparable with ‘anecdotal’ literary and iconographic evidence.

Finally, this chapter has focussed on macroscopic rather than microscopic and biomolecular analyses of faunal remains, partly because the former dominate study of the *consumption* of *dead*stock, while the latter primarily shed light on the *husbandry* of *live*stock. Husbandry histories are also relevant, however, to the distribution and consumption of animal products. For example, at Owlesbury in southern England, strontium isotope analyses of cattle teeth are compatible with local rearing of cattle consumed in the Iron Age, but indicate more distant sources in the Roman period (Minniti et al., 2014). At Roman Sagalassos, linear enamel hypoplasia defects in pig teeth suggest seasonal growth checks in free-ranging animals, but dental microwear indicative of a soft diet suggests a final period of stall-feeding and fattening

(Vanpoucke et al., 2009). Dental microwear, reflecting diet in the days or weeks before death, may thus shed light on the culturally and nutritionally critical, but otherwise obscure, issue of whether animals were killed in prime (fat) or poor (lean) condition. Finally, at Late Iron Age Levroux les Arènes in central France, sequential analysis of temperature-sensitive Oxygen isotope ratios in pig teeth indicates births at various times of year, with the implication that the concentration of deaths during a short period in the animals' second year represents slaughter not in a particular season but at a consistent age. This in turn may reflect a desire for hams of a standardized size, export of which has been inferred from the underrepresentation of pig femurs (thigh bones) (Frémondeau et al., 2015). Increasing application of such approaches to animals consumed in different contexts has the potential to determine, for example, where and how sacrificial victims were reared (King, 2005) and whether their husbandry histories differed from those of animals distributed through urban butchers.

Zooarchaeological data and methods are revolutionising our understanding of Roman animal management, distribution and consumption, and of the contribution of animal produce to Roman nutrition, cuisine and social dynamics. Together these insights are shedding a wealth of piecemeal, qualitative light on ancient historians' questions concerning the structure and performance of the Roman economy, even if quantified zooarchaeological assessment of economic performance is unattainable.

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Figure captions

Figure 1. Frequent stages of carcass reduction for cattle on Roman urban settlements

a. heads and feet (shaded) discarded in primary butchery; horns and toes (shaded black) discarded during horn and hide working, respectively
b. shoulder (shaded) cured in brine or smoke
c. long bones (shaded) chopped to extract marrow, grease or glue

Figure 2. Numbers of mandibular first molars (vertical axis) at successive stages of eruption and wear (horizontal axis), with approximate ages in months (after Jones, 2006). Assuming spring lambing, peaks around 0-2 and 8 months of age imply

slaughter in spring and autumn

Figure 3. Numbers of identified and recorded animal bones by century for sixth century BC-eighth century AD in (a) Italy, (b) provinces (mainly transalpine) of Roman Empire