A Biometric Study of Equids in the Roman World

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Abstract

Arguably horses and their close relatives have been amongst the most important domestic mammals in the history of human development. Equids have provided benefits to humankind that other domestic mammals were unable to offer: – specifically their ability to be trained and ridden. Equids were particularly crucial to the expansion and success of the Roman Empire.

The equids studied for this thesis were the horse (*Equus caballus*), the donkey (*Equus asinus*) and their hybrid the mule (male donkey x female horse). The first major area of research focused on the discrimination of the bones of these equids. A new methodology, using discriminant function analysis on biometric data, was developed to enable the positive identification of these equids. This methodology was then applied to a large set of archaeological data to determine whether there was a real discrepancy in species proportions between the contemporaneous literature and the zooarchaeological record. It was discovered that the hitherto perceived difference was caused by identification problems and that mules were ubiquitous across the Empire.

Withers height estimations, shape index and log ratio calculations were carried out on the identified equid material to look at differences between various groups of data. It was established that Roman conquest had an effect on the physical appearance of horses in the Empire. This effect varied considerably and although improvements in size were universal the appearance of the Roman horses was found to vary according to the differences in the preceding Iron Age stock, corroborating the contemporaneous literature and art historical sources. It was also determined that the trade of, and use of, equids was evident from the presence of mules and donkeys in areas external to, but contemporaneous with, the Empire.

This study shows the potential of a synthetic biometric survey of a single family of animals, within geographic and temporal limits, once the problem of identification has been overcome.

4

Contents

List of figures

List of Tables

List of Appendix figures

List of Appendix tables

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Author's Declaration

I declare that to the best of my knowledge any previously published material included here has been acknowledged as such and that the rest is my own work.

Chapter One – Introduction

1.1 Subject to be addressed

Arguably horses and their close relatives have been amongst the most important domestic mammals in the history of human development. Equids have provided benefits to humankind that other domestic mammals have been unable to offer, specifically their ability to be trained and ridden. This ability has influenced the later prehistory and history of most of the Old World, from the Assyrians, Egyptians and Scythians, through the Greek and Roman civilisations, to Genghis Khan, the European medieval feudal system and the Crusades; all have been aided by and have relied upon equids (Clutton-Brock 1992: Peters 1998). The more recent history of the European conquest of the New World was also successful because of horses.

In the introduction to the book *Equus: the horse in the Roman world* Hyland (1990: 1) states that:

> In many ways we are the inheritors of Roman expertise. With regard to the horse there are many links in the way we ride him, the equipment we use, the veterinary care he receives, his nutrition and general care. Most telling is the way he is trained, particularly for military use: his display of talent on the parade ground, the elaborate tack he carried, the very considerable weight of rider and armour under which he was expected to perform to optimum efficiency. Today many riders benefit from the methods used to train the Roman cavalryman and their mounts to a high degree of proficiency.

In addition to this, the practice of breeding animals to fulfil specific roles was initiated at this time and has continued down to the present day (Peters 1998). This process has resulted in the very great variety of equid breeds we have today, many of which have been bred for specific purposes, from the Shetland, Dales and Welsh ponies to the heavy draught horses and racing Thoroughbreds.

Equids were particularly crucial in the expansion and success of the Roman Empire. This was at least partly due to military foresight in making full use of the equids available, not only as cavalry but to move infantry from place to place and to provision the army both on campaign and at base. In addition to military use, equids were important in trade and communications both within the Empire and across its borders. Horses also played a part in providing entertainment for the populace in chariot races and other entertainment within the circuses and amphitheatres around the empire. 'Despite its complicated political and social structure the Roman Empire depended entirely on oxen, mules, donkeys and horses for all its land transport and postal service'(Clutton-Brock 1992: 118).

> Without its mule-borne baggage the legions would have found it virtually impossible to operate. As frontiers extended cavalry increasingly became a military arm in both size and importance. Without the racing fraternity and their passionate addiction to sport the circus would not have existed. Efficient transport haulage by land would have been non-existent, hampered and slowed to oxen pace. The cities' bakery mills would have lacked motive power and bread risen in price. Rapid communications, so vital in a military state, would have been absent (Hyland 1990: 2).

It has even been said (Clutton-Brock 1992) that a lack of horsepower was one factor in the eventual decline of the Empire, when better mounted 'barbarian' groups, more experienced in fighting from horseback, gained the upper hand.

Although a limited amount of information on these matters is available from contemporaneous literature, there are many aspects of Roman equids and their interactions with humans that remain unknown. These include such details as the sizes and shape/build of the equids of the Roman world, the movements of equids around the Empire and the ratio of horses, donkeys and mules used for different purposes in different areas. Many of these aspects may well have been considered common knowledge by the Roman authors and therefore not worthy of mention. Alternatively, some aspects may have been treated as secret, such as the breeding of chariot horses, or too specialised for general writers to concern themselves with. However, many of these aspects are of interest to archaeology and zooarchaeology as they can elucidate details of life in the Roman world that were previously unclear.

Some information has been gleaned from the archaeological record, but it is scattered throughout innumerable publications and archives, originating from countries in all parts of the former Empire. The aim of this project was to bring together what is currently known about equids in the Roman world and to extend that knowledge through further analysis of the zooarchaeological evidence.

Before going any further it would be beneficial to describe exactly which animals I will be dealing with in the course of this thesis. The horse family (Equidae) includes horses (*Equus caballus* L.), donkeys/asses (*Equus asinus* L.), half-asses (onager, khur and kiang *Equus hemionus* ssp.) and zebras (*Equus burchelli* etc), together with their hybrids. The taxonomic nomenclature of species that have extant wild and domestic forms is the subject of much debate. The issue is discussed in more detail in the terminology section (1.5) below, and the nomenclature used above and throughout this thesis is that recommended by the International Council for Zoological Nomenclature in an article in their Bulletin (Gentry *et al*. 1996).

In relation to the hybrids it is worth mentioning that the different species of Equidae have different diploid numbers of chromosomes, therefore their hybrid offspring have an odd number of chromosomes resulting in the vast majority of these animals being sterile because the odd number cannot be divided to make equal gametes. Domestic horses have a chromosome number of 64 and donkeys of 62, leading to mules having 63 chromosomes (Clutton-Brock 1992). Occasionally mules do produce offspring but this is such a rare occurrence that the Romans had a phrase *cum mula peperit,* 'when a mule foals', similar in usage to 'when pigs fly' and 'once in a blue moon' (Kay 2002).

In the context of the Roman Empire it is possible that the remains of all the species mentioned above could be found in archaeological assemblages dating to this period. However, half-asses and zebras, though sometimes tamed, have never been domesticated and the only likely way they would be found in Roman assemblages is as casualties from one of the many animal spectacles put on to entertain the public around the Empire but mostly in Rome. Wild horses and donkeys were also used in these spectacles (Hyland 1990). However, it is unlikely that any of these would be found in the vast proportion of archaeological assemblages from around the Empire and, taking this into account, they have been excluded from these investigations. Consequently, the following work is based on the main domestic equid species: horses, donkeys and the hybrid mules (Figure 1.1).

Figure 1.1 Pictures of modern equids. Clockwise from top left horse (Arabian), pony (Highland), mule and donkey. (Arabian from Archer 1992, Highland and donkey author's photos, mule courtesy of T. P. O'Connor)

1.2 Introduction to current research themes in studies of the Roman world

In 1888 Pitt-Rivers wrote 'it is next to impossible to give a continuous narrative of any archaeological investigation that is entirely free of bias; undue stress will be laid upon facts that seem to have an important bearing upon theories that are current at the time while others that might come to be considered of greater value afterwards are put in the background or not recorded' (quoted in Luff 1982).

Despite more than a century of archaeological investigations since Pitt-Rivers' statement, it is still true that current research themes, theoretical frameworks and methodologies play a major role in the way in which the discussion of archaeological material is targeted. Indeed in 1999 Goodman wrote that the choice of a framework for the discussion on Roman archaeology and literature studies is without doubt influenced by the taste and prejudices of the writer. This inevitably leads to bias in what is included and, perhaps more importantly, what is not included in any given publication. Goodman (1999) also suggests that, whilst new evidence often requires a shift in perception, this should be a matter for rejoicing rather than regret as new evidence invariably fits another piece into the puzzle, even if requiring the moving of other pieces first.

In addition, because of the time period over which books in particular are written and published, they are often slightly 'out of date' by the time they emerge. Journals are to some extent more current in terms of the research themes they address because the turn around time is quicker. Therefore, with the constraints just outlined, taking an overview from a selection of recently published books and current journals can give an impression of the current research themes pertaining to the sub-disciplines of archaeology. However, because of the diversity of these sub-disciplines within archaeology, there is inevitably great variety in the current research themes of each discipline. Therefore, the interaction of two or more disciplines can converge the current research themes and enhance the understanding of a particular topic by providing a fresh perspective on the evidence available.

It is hoped that the application of zooarchaeological techniques and evidence to the study of equids in the Roman World will bring about a better understanding of their role within the systems of the Empire. Conversely it is hoped that by integrating the information from Classical texts and archaeological knowledge of the Roman World into the results of the zooarchaeological analysis of equid remains, a better understanding of observed trends can be obtained.

It would not be practical to review all the current research themes in Roman archaeology, so this section has been limited to covering those themes that are considered most appropriate to the interpretation of the subject of the thesis. These include studies of the process of Romanisation (1.2.1), the degree of regionality in the Empire (1.2.2), discussion of frontier zones (1.2.3), the impact of the Empire on communities beyond the boundaries (1.2.4), the question of trade and supply to both the army and civilians (1.2.5) and the end of Roman rule (1.2.6). Many of these topics interrelate as would be expected for a series of themes essentially concerned with the same broad subject. During this section and the rest of Chapter 1, the areas of research that this project will attempt to address will be highlighted as bullet points with the heading 'Research aims'. The questions posed in this manner will be those that will be enlarged upon in Chapter 7, although not in a question and answer format but as a discussion of the issues.

1.2.1 Romanisation

Following the order outlined above, the first topic, 'Romanisation', is one that recurs as a research theme in the archaeology of the Roman period. Romanisation is usually the term used to describe the process of 'becoming Roman' when an area was conquered. Traditionally this has mostly been written about from the viewpoint of the conqueror changing Iron Age barbarians into civilised provincial Romans. The assumption that the Roman authority was the dominant force may be relevant in some areas, but needs careful thought before use (Barrett and Fitzpatrick 1989). Wells (2001) suggests that this is a one-sided view of what was actually a two-way process and that these same Iron Age societies were actually in the process of 'Romanising' themselves through contacts with Mediterranean cultures before conquest took place. Fitzpatrick (1989) also indicates that the indigenous elites adopted some aspects of 'Romanness' to their own advantage prior to conquest.

Wells (2001) argues that the conquest was only an intensification of interactions that had taken place for some time and therefore, that modern research should focus not just on the effects of conquest and imperial administration on indigenous peoples, but also on the active roles played by those peoples in the construction of the new colonial societies. Fitzpatrick (1989) also advocates this approach and suggests that the indigenous people played an important role in the integration of their communities into Roman Empire rather than receiving Roman contact passively.

These interactions probably took many forms, such as diplomatic relations, military alliances, mercenary service and trade and exchange, the last two being perhaps the most visible archaeologically (Fitzpatrick 1989). Aspects of trade and exchange are discussed below. The exact nature of these interactions varies widely through time and in different areas. In some cases these interactions took place prior to conquest, whilst in other areas these were ongoing interactions across a relatively stable frontier zone as discussed below. These different situations required diverse interactions to achieve the aims of the Empire, i.e. the expansion or stabilisation of frontiers.

Another aspect of Romanisation is the effect of veteran colonies on an area. These veteran colonies were founded deliberately to settle people loyal to Rome (i.e. ex-soldiers) in a newly conquered area to serve as a deterrent to rebellion. This was started in Italy but gradually spread to other parts of the Empire as conquest proceeded. Therefore the veteran colonies formed a focus for Romanisation within areas of the Empire (Goodman 1999). These colonies would have attracted trade, as the ex-soldiers, who would have become accustomed to the Roman way of life during their military service, formed a demand for Roman goods.

- ❖ **Research aims.** In the light of the above research theme, there are several areas that can be addressed in relation to equids. For instance, what effect did the Roman conquest of a particular area have on the physical appearance of horses in that area? Were any changes the result of a process that started pre-conquest and was continued afterwards and is therefore manifested as a gradual change? Alternatively, are there any detectable changes between immediately pre- and post-conquest horses suggesting a sudden change consequent upon the conquest?

1.2.2 Regionality

The next research theme is intimately related to the process of Romanisation in general as it is the study of regionality within the Empire. This is the study of differences between the degree and nature of Romanisation in different provinces. The study of regionality in the Roman Empire is the topic of a forthcoming conference session, making it a very current research theme. It is highly likely that the written sources overstate the degree to which the material culture and lifestyle in the provinces became 'Roman', because these authors were mostly based in the heart of the Empire and were themselves biased towards 'Romanness' (Wells 2001).

The word 'Romanisation' implies a standard process, and Wells (2001) argues that it is very clear from both the archaeological and epigraphic evidence that the differences between the conquered societies in various areas meant that the character of the interactions was different and therefore the process could not be standard. The archaeological evidence also shows a complex combination of indigenous traditions and elements introduced by the Roman military and administration, and which elements of each culture were combined depended on local needs and traditions. This means that the 'Roman citizens' of different provinces adopted the Mediterranean Roman traditions and culture in many ways and to a varied extent (Wells 2001). The pattern of change was different across different regions and each community experienced the changes differently. These differences are spelt out in the work of Goodman (1999), who devotes a chapter to each province (or group of similar provinces) to explain the politics and administration, the cultural makeup pre- and post-conquest and how the process of Romanisation manifested itself. It seems that the dominant aspect of these communities was diversity (Wells 2001), which is almost the opposite of the traditional view of uniformity across the Empire.

Recent studies (summarised in Goodman 1999 and Wells 2001) have shown that many communities did not adopt Roman styles as eagerly or as rapidly as others in their region did, either because they could not afford to do so, or in many cases, because they chose not to. Therefore, whilst the architecture of public buildings, and acquisition of portable material culture such as pottery and coins, display a remarkable degree of uniformity across the Empire, from Britain to North Africa, Spain to the Near East, it is important to bear in mind that this homogeneity was restricted to the elites of the provinces. And yet even in these aspects the details of the distribution of the items of portable material culture reveal that there are differences between regions. The opposite of this uniformity can often be seen in the exaggerated expression of regional identities in material culture and architecture amongst non-elites in many areas (Wells 2001). Indeed it has been demonstrated that in Upper Moesia there was an area within the Empire south of the frontier zone that was all but devoid of Roman presence (Whittaker 1989), and a similar lack of Romanisation has been observed in the uplands of northern England behind the frontier (Higham 1989). It may be the case that these areas lacked enough social stratification to be predisposed to Romanisation. In contrast, the southern and eastern areas of France were quickly and extensively Romanised. This was partly the readiness of the elite to adopt Roman culture and the opportunities offered in economic terms by the role of the region in redistributing goods to the frontier zones further north (Goodman 1999).

Wells (2001) suggests that the term 'Roman' should not be applied in the context of temperate Europe and that the term 'Romanisation' should not be used to describe the process of post-conquest interaction. In this thesis these terms will be used but with less rigidly defined meanings, namely 'Roman' to denote material belonging to the post-conquest period of archaeological sites and 'Romanisation' to denote any observed changes that could have been caused by interactions resulting from the conquest of an area.

- **Research aims.** In relation to this research theme there are two areas to be questioned within this study. Firstly, was there variation in the ratios of different equids throughout the Empire? And secondly, were there differences between the physical appearance of horses from diverse areas of the Roman Empire and were these characteristics consistent through time?

1.2.3 Frontiers

The third research theme is another that has regularly received attention and concerns the frontiers or boundaries of the Roman Empire. In the 19th and 20th centuries, in Britain and Germany in particular, the physical remains of boundaries represented by Hadrians Wall (Britain) and the *Limes* wall (Rhineland) were studied intensely. At this time the frontier was presented in the literature as an actual barrier, be it a wall or a river, that could be drawn as a line on a map. Another aspect was the influence that modren empire thinking had on the works of people such as Haverfield in Britain and Mommsen in Germany (quoted in wells 2001), where they tried to emphasise the order and organisation of the Romans in order to justify some of the aspects of those empires. Also in Germany, the division of the east and west after World War II influenced the writings from both sides of that divide about both sides of the Roman frontier (Wells 2001).

During this time the frontiers were seen as military defences, and whilst they were certainly military, careful examination of the positioning and nature of the boundaries has revealed that they were not particularly defensible in the traditional sense. They can be seen more as an aid to controlling the movement of people and goods rather than repelling invasions. The idea of the frontier zone containing the friendly kings was more for defence than the often fragmentary physical barriers.

The idea of a frontier is a difficult concept to study when the Roman civilisation had little or no conception of the idea, particularly during the republic and early empire (Fitzpatrick 1989). This ambiguity is illustrated by the tribes who signed treaties with Rome to become client or friendly nations. These tribes were legally speaking outside the Empire, but the degree of interference from Rome in their affairs suggests they were regarded as part of the territory.

Therefore, Rome considered them as within the boundaries in some respects and outside them in other respects, leading to great ambiguity in the definition of boundaries in this period (Hanson 1989). The concept of frontiers became more apparent during the Empire period as the horns of imperial expansion were withdrawn and more or less stable boundaries were established (Fulford 1989), to the extent that Aristeides writing in the 2nd century AD lays importance on the 'walls surrounding the Empire' (Hanson 1989).

Modern thought is turning towards the idea of the frontier being a 'zone' rather than a line at a barrier. This has been through comparison with other frontiers worldwide and in particular the western frontiers in 18th and 19th century USA and those of the British Empire elsewhere. These comparisons have elucidated the fact that the frontiers can be quite broad zones of intense interaction between the peoples living on both sides of the actual boundary line (Wells 2001). The dynamics of these well-documented, recent, frontier zones have allowed the archaeological evidence to be reassessed and better understood. For instance, the frontiers of the Roman Empire are now considered to be areas of interaction between cultures as well as the interface between the army and native opposition (Hanson 1989). These frontier zones may or may not include a marked boundary within them.

Although the frontier zones in the Rhineland and Britain are perhaps the best studied, other frontier zones did exist in the Roman Empire. These include the frontiers in North Africa and the Levant. The limited amount of study that has been carried out on these suggests that similarities existed between all the frontier zones, particularly in the effects of a heavy military presence (Goodman 1999). However, they are each unique in the manner in which the boundaries are defined and the effect they had on local populations on both sides of the frontier itself. In some respects the study of the regionality of the Empire encompasses the study of the frontier zones as it presents particular patterns on a regional level, therefore the research aims outlined above also apply here, as well as the one outlined below.

- ❖ **Research aim**. In this study, research into frontier zones brings forward the question of whether there were differences between the equids of different elements of society, i.e. those from military, urban and rural sites. This applies to other areas as well, but the frontier zones may show the concentration of military animals.

1.2.4 External contact

Related to the frontier zones are of course the areas beyond the boundaries of the empire, and the next research theme concerns the impact of the Roman Empire on these areas. The literary sources say next to nothing about trade or contact with those beyond the boundaries of the Empire except in the immediate frontier zone. However, it has become apparent from archaeological excavations that the extent of Roman influence was far greater than had previously been thought. The sources mention the use of tributes and gifts to the 'friendly kings' in the immediate frontier zone as a means of keeping them amenable and therefore helping protect the Roman boundary, and also the use the friendly kings made of these gifts to bolster their own position in society and hence maintain stability (Braund 1989). These gifts to friendly kings sometimes included horses, as mentioned by Caesar in relation to the Gauls. These gifts also took the form of permission to trade within the Empire and therefore acquire weapons and horses that were forbidden to those hostile to the Empire (Braund 1989; Hanson 1989).

Much of the influence the Empire had on the communities beyond the boundaries was through trade, so this links with another research theme, that of trade and supply, which is covered below. Indeed Wells (2001) maintains that trade with the peoples beyond the frontier was so important that without the foodstuff, raw material and other goods that were produced by these communities Rome would not have been able to maintain the military presence and urban centres in the frontier zones and, elsewhere in the Empire.

Different communities felt the influence of the Roman Empire in different ways. For those close to the boundaries, the intense interactions of the military frontier zone would have had a major impact on their lives, economies, traditions and social organisation (Wells 2001). The quantity of Roman products in the frontier zones suggests that the communities living in these areas favoured Roman products and went to some effort to acquire them. However, the distances involved suggest that no particular organisation of the trade need to have taken place: individual entrepreneurial merchants could have travelled into the areas to trade and farmers bringing goods to the military and urban centres could have traded within the Empire (Fulford 1989; Wells 2001). The political stability gained through the tribute system to friendly kings would have the added effect of allowing economic growth in the communities of the frontier zone by allowing agricultural surplus to be produced and trade to be established.

It is noticeable that the quality of the imported items is better the greater the distance from the borders, with larger quantities of everyday items in the frontier zones and the most exotic and valuable pieces at long distance such as in Denmark and Poland (Whittaker 1989, Fulford 1989, Wells 2001). This perhaps reflects the difficulties involved in long distance trade and therefore the fact that the status of the goods had to make this a worthwhile exercise.

- **Research aims.** Here the obvious question to ask is were there differences between horses within the Empire and those beyond, particularly areas with close contacts such as the Rhineland? Also, how far did any discernible Roman influence on the equine population extend beyond the Empire?

1.2.5 Trade and supply

Related to all of the research topics mentioned above is the question of the trade and supply of material goods and foodstuffs, amongst other items, within and beyond the Roman Empire. The concentration of troops in the Rhineland and the foundation of veteran colonies provided a huge boost to the economy and the Rhine itself became a trade route, protected by the Rhine fleet (Goodman 1999).

Regarding the Empire, a major concern of most who study trade and supply is the supply of the standing armies along the frontier zones mentioned above. There is much debate as to whether the armies could have been supplied from within the Empire either locally or long distance or whether there was trade externally for supplies. Turning first to supply from within the Empire, it is surmised that a specialised system of supply to army developed. Like supplies for Rome, the army could not afford to chance the vagaries of the harvest in local areas, grain **had** to be supplied by whatever means. Some of the long distance routes can be worked out from such things as the distribution of amphorae and other ceramics (Middleton 1979; Whittaker 1989). These studies suggest an organised gathering of supplies for the army and direct transportation, using the rivers of France as a major distribution network (Middleton 1979; Whittaker 1989). This work was undertaken by *negotiatores* (Whittaker 1989) and the transportation was done by specific fleets, either under contract to (*navicularii*) or belonging to the army (*classis Germanica* and *Brittanica*) (Middleton 1979).

Presumably mules and donkeys must have been kept for the transport of supplies along the short distances from the production sites to the rivers and the rivers to the forts, either to pull wagons or as pack animals. Donkey trains are mentioned in the context of ceramic transport from La Graufesenque to the Frontier as this site was on the route from the mining regions of Ruteni to Narbonne along a military route (Whittaker 1989). The transportation of the goods demanded as taxes was possibly also a tax requirement (Middleton 1979), so mules and donkeys must have been used at a local level for this transportation, at least to centralised collection points, i.e. river ports. During the conquest of Britain road transport must have been used to supply the army as the river and sea routes had yet to be secured (Middleton 1979). Tacitus refers to the above-mentioned tax demands of transportation in the British context in his account of *Agricola* (19.4 quoted in Middleton 1979).

Groenman-van Waateringe's (1989) study of the palaeobotanical evidence and agricultural practices in northern Europe has elucidated much about the supply of grain to the army. The army's preferred cereal was wheat but the soils and climate of much of the lower Rhineland, in particular, were not suited to wheat raising. Therefore, wheat must have been imported from outside the immediate hinterland of the frontier zone. In wheat producing areas, an increase in production and storage is denoted by the replacement of small square granaries with large buildings over 20m long. As previously stated this would have required equine transport at least at the local level.

The specialised army supply trade spilled over into civilian areas en route to a limited extent. Long distance trade was at least dependent, if not parasitic, on official supply lines (Middleton 1979). This suggests that little trade existed outside these mechanisms. However the extent of the evidence for trade amongst civilians indicates that this must have been sufficient to supply needs. Alternatively there may have been other trade routes or supply mechanisms that have yet to be established. Part of this may be the issue that many of the traded goods were part of what has been termed the archaeologically invisible import and export trade, i.e. those things that are perishable or for which there is no means of immediately identifying area of origin, unlike amphorae (Fitzpatrick 1989). Trade in equids, as mentioned in Livy and Caesar's *Bello Gallico*, or the use of equids in trade is one area that falls into this category.

This last issue of the trade in equids is one that leads onto the trade with areas outside the Empire, as this is what Caesar and Livy mention. Previously it has been suggested that trade across the borders was facilitated by the frontier being a zone where friendly societies could be traded with. This trade was one of the interactions that took place between Rome and external societies both prior to conquest and along frontier zones as mentioned above.

There is evidence of quite extensive trade with Gaul in the 2nd and 1st centuries BC and this has been shown (Fitzpatrick 1989) to have a been a complex and extensive network of contacts between Gaul and both Italy and Spain. In the frontier zones, the area east of the Rhine is well documented for the trade contacts that took place. The texts mention the purchase of livestock, in particular oxen and horses, as well as grain and amber from this area (Wells 2001). In addition to the Rhineland, the plains across the Danube and the lowlands of Scotland fulfilled this role (Whittaker 1989). Indeed, Whittaker (1989) suggests that one reason for the quite rapid retreat to Hadrian's Wall soon after setting out further north was the guarantee of supplies without the need for annexation.

The immediate frontier zone (i.e. within 60 miles of the boundary) has been discussed above so this section is confined to the longer distance contacts and trade. The presence of *terra sigillata* pottery, bronze wine equipment, wine and oil amphorae, olive stones, jewellery, glass vessels and coins in some quantity on many sites beyond this frontier zone hints at quite a considerable degree of trade interaction. The distribution of sites with such finds extends into Germany east of the Rhine, Denmark, Sweden, Poland and Moravia.

In the 60 to 240 mile zone (Wells 2001) it is evident that some communities changed their economies in order to benefit from trade with the Empire. Fedderesen Wierde is a good example, where the inhabitants intensified cattle production to trade meat and hides to the frontier zone (Wells 1996). Another reason for fairly intense trade in this zone is that many auxiliary soldiers returning to their homelands in this region brought Roman objects with them and stimulated a need for goods and material culture to continue the life they had become accustomed to.

At even greater distances (beyond 240 miles from the frontier) the most spectacular imports have been found in association with some of the largest and most complex commercial centres for supplying goods to the Roman provinces. These sites include Jakuszowice in southern Poland, where high quality imported Roman goods were traded for iron ore and other metals from the Holy Cross Mountains. In Denmark, the excavation of the 'Kings Hall' at Gudme (a very large aisled building) produced a staggering quantity of high quality Roman imports. The associated harbour site at Lundeborg seems to have been set up specifically for seasonal use in the summer when shipping was active.

In both these cases the associated cemetery sites show that most of these lavish imports were destined for the elite of these communities suggesting that the elites controlled production of the raw materials and craft items that the Romans wished to trade for. Another view is that because it was considerably cheaper to transport goods by sea than by land, supplies destined for areas east of the Rhine would most likely have been transported around Denmark to the Baltic coast of Germany, and therefore establishing trading posts and hence safe harbours en route was a sensible approach (Greene 1986).

Although trade undeniably took place, Goodman (1999) suggests that the imported artefacts did not greatly alter the established lifestyles of those beyond the boundaries of the Empire, but Wells (2001) suggests that many did take advantage of the economic opportunities as outlined above.

The issue of trade and supply seems initially not to be connected to the study of equids until it is remembered that equids were essential to the transport of people and goods across the Empire. Perhaps the most obvious form of equid transportation is the hauling of wagons. Until recently it was considered that the designs of Roman harness and the wagons themselves prevented efficient haulage by equids. However, recent work using replicas has shown that this was not the case and that equids were an efficient means of traction as long as the terrain was not difficult (Greene 1986). The discussion of the importance of rivers in long distance trade and the supply of garrisons (e.g. Middleton 1979) has tended to underestimate the use of mules as pack animals, particularly in areas of hilly terrain and over short distances (Greene 1986). In areas such as central Italy and Greece, mules were superior beasts of burden as a string of 20 mules could carry as much as five ox-drawn wagon loads. Donkeys were also commonly used as beasts of burden, often being bought with the load and sold along with it at the destination.

It is noticeable that there are many carvings from northern Gaul depicting the use of equid drawn wagons and from these it has been deduced that technical improvements in harnessing took place in this area. It is argued that the terrain in this area was ideal for wagon transport and that the agricultural surplus produced there must have been transported to markets where it could be sold for enough profit to allow the quantity and quality of the local villas to flourish (Greene 1986). This suggests that land transport must have been efficient; otherwise the profits would have been lost in the high cost of transportation. The distribution of representations of equid drawn wagons and pack animals is extremely uneven, being common in eastern France and neighbouring areas but totally absent from Britain and Spain. Whether this regionality is a result of differences in the means of transporting goods or differences in epigraphic habit is difficult to determine, however it can be said that generalisations about transport cannot be made because each region relied in different proportions on land or water borne systems, depending largely on geography.

- **Research aims.** With reference to the army supply routes, can these long distance trade routes be detected in equid remains, for instance are there concentrations of mules and/or donkeys at producer or military sites as the first and last stages of the transport routes? Research aims connected to long distance trade outside the empire are essentially the same as for those given in the section on contacts outside the Empire so will not be repeated here.

1.2.6 Roman / post-Roman transition

The last research theme to be discussed is the issue of the end of Roman rule. This is a 'hot topic' of current research focussing on the extent to which roman pottery traditions (amongst other studies) carried on after the official end of Roman administration in an area and whether lifestyles changed dramatically or went through another more gradual shift as at the beginning of the period. It is becoming apparent that the Roman pottery tradition did extend past the official end of Roman administration and therefore the chronology of many sites can now be extended by as much as another century (Whyman 2001; J. Gerrard *pers. comm.*). This later dating of pottery from late Roman / early post-Roman contexts is only just being understood and therefore it was not be possible to use the data from already published bone reports, that had used the more traditionally accepted pottery dates, to address this issue at present. However, the extended chronologies will allow this to become an interesting area to study in the future.

The research themes within Roman archaeology outlined above are those that it is thought this study will be able to contribute to. Hopefully by addressing the research aims highlighted here and below, a new perspective on these research themes from both the Roman archaeology and zooarchaeological viewpoints will be gained.

1.3 Roman equids in art and literature

There are a great many references to Roman equids in classical texts and art, revealing a lot of detail regarding some aspects but virtually no information on other aspects of equid use. It is also highly probable that many equids in art historical sources are not all that accurately portrayed. The second item is one worth considering further at this juncture. The portrayal of equids in Roman art may not be accurate for a number of reasons, such as political motivation, ineptitude of the artist and artistic licence. The first point really concerns such articles as public monuments, where the artist has an obligation to portray the subject in a manner pleasing to the person paying for the monument (Figure 1.2). For instance, this could result in the horses of a defeated army appearing either inferior to those of the Roman cavalry to show the superiority of Rome, or the opposite to show how brave and wonderful the army was in defeating them.

Figure 1.2 Statue of the Emperor Marcus Aurelius.

Ineptitude of the artist could be the result of unfamiliarity with the subject (as in the case of the representation of exotic animals) or a real lack of talent: either way the resulting images would not be an accurate reflection of equids at that time (see Figure 1.3 for examples of poor artistic quality and Figures 1.6 and 1.8 for examples of high quality). Artistic licence could take many forms, such as the enlarging of an equid that was central to a story, for instance in a mosaic depicting the legend of Pegasus. Equally the artist could reduce the size of the equids when they are not central to the image, so as not to detract from the main theme (Figure 1.4). In relation to equids, it has been noted (Raepseat 1982 quoted in Greene 1986) that, because horses were an expensive and prestigious commodity, they were shown on gravestones in situations where they were not used in real life in order to increase the apparent status of the deceased.

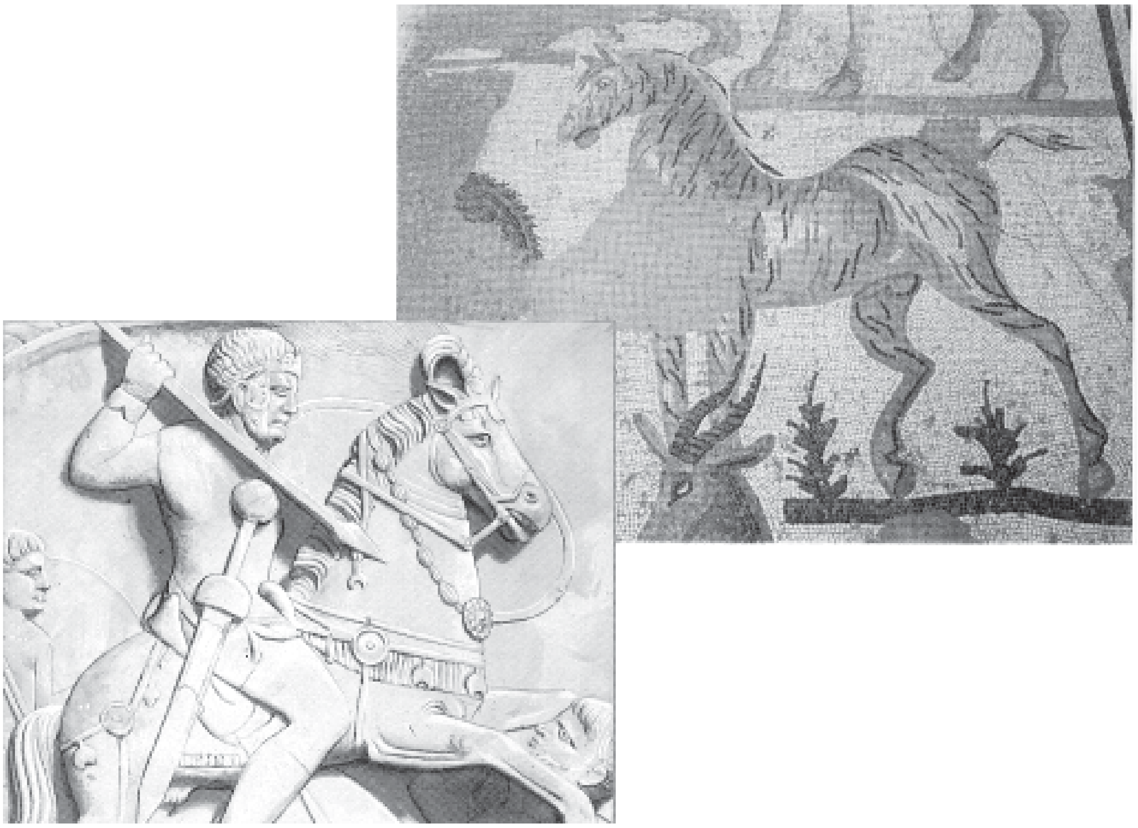

Figure 1.3 Examples of poor artistic quality. A zebra represented in a mosaic that is just a slightly stripy horse (top), and a carving of a cavalry man and his mount that is very oddly proportioned (bottom) (Mosaic from Ciurca undated; carving from Hyland 1990).

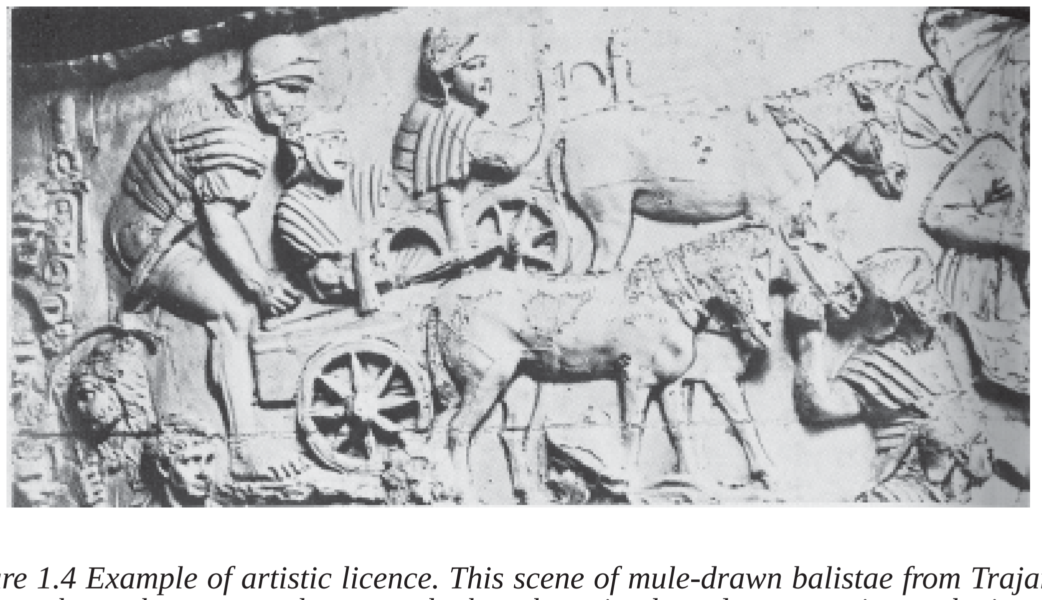

Figure 1.4 Example of artistic licence. This scene of mule-drawn balistae from Trajan's column shows the men at a larger scale than the animals to draw attention to the importance of the man rather than the mules (From Toynbee 1973).

In spite of all these arguments against the use of art historical sources as a means of understanding what Roman equids looked like, it is possible to make general statements by looking at many representations and removing the obvious outliers. Art historical sources can also give information about how equids were used in Roman society, and what species were used for what types of activities, which may help us to interpret the equid remains found on different types of archaeological site. Bearing in mind the considerations detailed above on the use of the art historical sources, there are a great many representations of equids in many Roman art forms. This plethora of depictions reflects the high standing horses had in the life, cult and customs of the Ancient World (Peters 1998). These images include statues, carved reliefs, tombstones, coins and mosaics (Toynbee 1973). Many of these are discussed below under the relevant section.

The snippets of information given in the contemporaneous literature are scattered throughout numerous documents covering a time span from the height of the Classical Greek civilisation to the end of the Roman Empire (*c*. 500 BC to *c*. AD 500). As with the art sources, there are inherent biases in literature too, because the understanding of the subject will colour the account given by each individual author. For instance many of the authors lived and wrote in Rome itself, or in Italy, therefore what is said about everyday life, economic factors and political administration cannot necessarily be taken as applying across the entire Empire (Goodman 1999), particularly given the great diversity mentioned in Section 1.2 above. In addition, did the author have a political motivation or other agenda for writing, or was it written for a particular audience? If this was the case then these biases need to be understood before a text can be used and interpreted (Wells 2001). In addition, the bias of those who wrote from Rome has a very 'us' and 'them' attitude to those beyond the boundaries of the Empire (Braund 1989). As the purpose of this thesis is not to analyse classical texts in detail, many of the quotes from Greek and Roman authors are derived from secondary sources. In particular the book by Hyland (1990), which draws together a great deal of information gleaned from ancient written sources, has been quoted extensively in the following pages.

The equids being studied here, horses, donkeys and mules, were used for a variety of purposes within the Roman world, which are generally separated according to species although there is some overlap. Horses were used as cavalry mounts, chariot racing, riding (transport and hunting) and occasionally pulling carriages (White 1970). Mules were mostly used for draught purposes (mostly road haulage but also for carriages), as pack animals (particularly in the army) and were occasionally ridden. Donkeys were used primarily for traction (turning mills and ploughing in areas of light soil) and as pack animals. The appearance of donkeys would have varied little, as is the case today, but both horses and mules would have shown considerable variation in appearance. Mules would have varied according to the type of mare used to breed from. Descriptions of mules are very scarce but descriptions of horses are much more prevalent.

1.3.1 Horses

Appearance

As a starting point in studying Roman equids it would perhaps be a good idea to use a contemporaneous description of the Roman 'ideal' horse. Both Columella and Pelagonius described this and the texts show remarkable similarities despite having been written three centuries apart. This could well be plagiarism (quite common in classical texts) but does show that over the three intervening centuries the ideal horse had not changed. Other writers, including Xenophon, Vegetius and Varro, also describe parts of the horse and most accounts agree as to the ideal to aim for. Columella's text reads as follows:

> Small head, dark eyes, wide-open nostrils, short upstanding ears; a neck which is soft and broad without being long, a thick mane which falls down on the right side; a broad chest covered with well-proportioned muscles, the shoulders big and straight; the flanks arched, the backbone double, the belly drawn in; the loins broad and sunken; the tail long and covered with bristling curly hair; the legs soft and tall and straight; the knee tapering and small but not turned inwards; the buttocks round, the haunches brawny and well-proportioned; the hoofs hard, high, hollow and round with moderately large coronets above them. The whole body must be so formed as to be large, tall, and erect, and also active in appearance and, in spite of its length, rounded as far as its shape allows. (Columella *r.r.* VI, 24, 2-3).

This ideal Roman horse is very close to modern descriptions of good conformation (e.g. Spooner 1990), with two exceptions. The first of these is the Roman preference for upright shoulders, which today is considered a fault as it gives the horse a somewhat vertical front leg action. This can be very showy but puts stress on the lower leg joints. The second point is the Roman liking of horses with small knees: again this puts extra stress on the joints of the lower leg and modern descriptions suggest they should be in proportion to the leg. Despite their limited understanding of anatomy and how conformation can affect performance, however, the Romans ideal horse would come close to modern expectations of a 'good' horse.

Peters (1998) gives a good account of coat colours and how some were considered good and others as useless. The *Mulomedicina Chironis* (quoted in Peters 1998) even describes the unscrupulous use of dyes and bleaches by horse traders to obtain a higher sale price for the animals! Generally a solid coat colour was preferred to a bi-coloured or roan (mixture of hair colours all over) one. White markings were also frowned upon. Of course there is no basis in truth that horses of a particular colour are better or worse than any others. However, where a deme exhibits a single or small range of colours and that deme is preferred for a particular use, it is easy to see that coat colour would be associated with other attributes.

Whilst this was the ideal to which Roman horse breeders aspired, there was still considerable variation between horses bred in different areas of the Empire. As discussed below (section 1.5) these are not breeds in the true sense of the word and will be termed demes. These demes seem to have had a relatively consistent appearance, which resulted from breeding within a limited gene pool over a substantial period of time. The improvement of local stock with imported stock was carried out in many areas, such as Gaul (Caesar: *De bello gallico*), even prior to the Roman period.

Most of the Roman authors who wrote about equids were concerned with their use in agriculture, their care from the veterinary perspective, their breeding and use in the chariot racing industry or their use to the military. Most of these authors were based in Italy and base their views of equids from other areas of the Empire on whether they were likely to be of use to the people undertaking each sphere of activity mentioned above. They generally showed favour for the demes that were useful in breeding certain types of animal for particular uses. Conversely, those demes that were considered of no value for breeding or use tended to be dismissed in no uncertain terms.

For instance, Varro (*r.r.*) indicates that three areas were renowned for good horses: Apulia, the Peloponnesus and Reate (where his own mule breeding stud farms were located). He also suggests that the best donkeys used for breeding mules come from Arcadia (Greece) and Reate. In addition to these areas, Vegetius (quoted in White 1970) suggests that cavalry horses were mostly barbarian horses from the Huns and Burgundians, those for the circus came from Cappodocia, Spain, Sicily and Africa, and those for riding came mostly from Persia, Armenia, Epirus and Sicily.

Many pieces of Roman and Greek literature contain descriptions of horses from different areas of the Empire. The names given to each deme generally refer to the area from which they originated and as this is the most comprehensible way of categorising the different groups. Figure 1.5 shows the demes described by classical authors together with a brief outline of that description. Most of the descriptions are taken from Hyland (1990) and their main uses from Peters (1998), which bring together the works of many classical authors.

❖ **Research aim.** From these descriptions there was evidently a great diversity of horses within the Roman Empire and detecting this in the archaeological record is one of the aims of this piece of research.

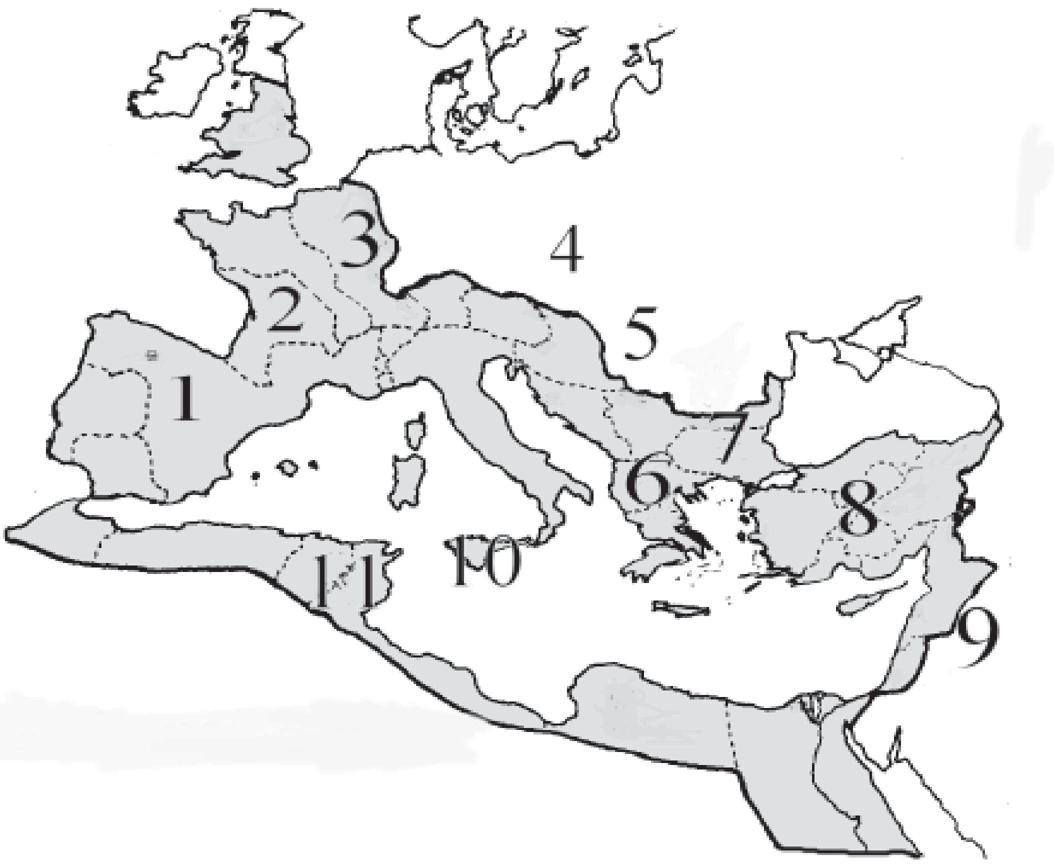

Figure 1.5 Map of the Roman Empire during the 2nd century AD showing the location of various horse demes as taken from the works of contemporaneous authors.

1) Spanish horses were used extensively by the military and also in racing. Oppian considered these horses to be small and 'weak-spirited' and whilst they were speedy over a short distance they had no stamina. A century later Nemesian considered them to have both courage and stamina, probably after the addition of Libyan blood during the middle of the 3rd century.

2) Gallic horses were considered to be small and ugly by Caesar (*B.G.* IV 2) when he

encountered them. However, the Gallic people had realised the potential for upgrading their stock using imported stallions prior to the Roman conquest. These improved animals were considered to be ideal cavalry mounts as they had great endurance and were bred for this purpose in large numbers.

3) The Germanic people had similarly small and ugly horses but Caesar (*B.G.* IV, 2) comments that were 'rendered capable of very hard work by daily exercise'. He also says that they were content with their own animals and did not import those of the Romans. Once the Romans had conquered they imported larger horses in numbers.

4) Vegetius described the Hunnish horses as eminently suitable for war, because although they were not pretty they were excellent mounts for soldiers who were not experienced horsemen as they were strong enough to carry the weight a long distance and were also easy to manage. They were tall and long in the body with thin belly and big bones. In more detail they had roman-noses, a narrow nose, broad jaw, strong and stiff neck, long and narrow bodies with a bent back and hollow flanks, strong cannons and dinner plate hooves. Vegetius also says that their temperament was moderate, they were calm, could endure wounds, were trainable, able to work hard, and could withstand cold and hunger.

5) Descriptions of Sarmation horses are scarce in the literature but Strabo tells us that they were small, fast and hard to manage, whilst Pliny the Elder indicates that they had great endurance.

6) Herodotus considered the Thessalian horses were the best in Greece but were no match for the Persian animals. However, the Persian invasion saw thousands of cavalry stationed in Thessaly and these horses left their mark on the local population. This went a long way to improving the local stock, so that by Roman times the Greek horses were considered one of the superior demes and were mainly used as cavalry mounts.

7) Thrace was producing 'huge' horses as early as the time of Homer (*Iliad*). Even given the fact that at that time most horses were pony-sized, these must have been substantial animals. Homer also comments that many were white in colour. Gratius Faliscus commented that they were 'easy keepers and excellent performers but with ugly necks and thin spine curving along their backs'. Evidence of the horse trade between Thrace and Greece and Persia is indicated by the description of large white horses from the latter two areas as well.

8) Because of the degree of crossbreeding between the Nisean, Median, Armenian and Cappadocian horses they are included as a group. The Cappodocian horses are mentioned particularly as good racehorses and also as good carriage horses.

9) Many classical authors rated the Parthian or Persian horses very highly. Oppian describes them as handsome, courageous, gentle to ride, obedient, swift, spirited, war-like and strong with small heads. Strabo describes them as the 'best and largest' and Nemesian calls them 'huge'. The Apadana frieze at Persepolis shows large, heavy, high crested, well-muscled animals with slightly convex head (in profile). This descriptions and depictions are close to the Roman ideal horse hence the favourable reports. The Persian horses were mainly used as riding animals.

10) Sicilian horses were particularly regarded as racehorses and also as riding animals, but little in the way of description seems to have survived.

11) The Libyan horses (Numidian/Libyan/African used as interchangeable terms) were considered by Livy to be small and ugly, but Nemisian and Strabo recognised them as being obedient, fast and with great powers of endurance. The reference to their small size may refer to their slender build rather than their height, as many were about 1400mm. They were highly regarded as cavalry mounts and were often used to impart endurance when improving other demes. They were also excellent carriage horses.

Breeding, training and caring for horses

The breeding of horses in the Roman period was carried out at two levels: the large studs owned by the state and wealthy landowners, and the small-scale landowner with one or two mares. Much of the material written about horse breeding is in relation to the large studs. However, the principles of breeding a horse are the same whether you have one or a hundred mares. As most large studs bred horses for a particular purpose, the characteristics of the mares and stallions would be chosen with this in mind. As has been discussed above, different areas bred horses with different characteristics more suited to one or another of the equestrian fields. In attempts to improve stock, stallions were frequently imported from other areas as the Romans thought the stallion was decisive in imparting physical characteristics to the offspring (Peters 1998), whereas the Greeks considered the attributes of the mare more important.

Columella (*r.r.* VI, 27) tells us that there were three types of horse breeding stock. The first was the noble stock (*materies generosa*) for breeding chariot-racing horses (and probably also ceremonial and military horses), the second (*materies mularis*) was the stock used for breeding mules (almost as highly rated as the noble stock) and thirdly the common stock (*materies vulgaris*). There were different husbandry regimes for breeding from these types of stock. For the common horses, the stallions ran free with the mares all year round. For the quality stock, supervised mating took place around the spring equinox, the stallion being kept indoors or far away at other times of the year.

Varro (*r.r.* II, 7) kept one stallion to every ten mares, whilst Columella (*r.r.* VI, 27, 9) suggested 15 to 20 mares to one stallion. A teaser stallion was often used to test a mare's readiness to mate (Columella). This is often still done today, particularly in thoroughbred breeding, so that the very valuable mare and stallion are not injured if the mare kicks out when not ready to mate. Columella (*r.r.* VI, 28) says a stallion can cover mares between the ages of 3 and 20. Pliny suggests 33 as the upper limit. Stallions were used to cover mares whilst still working as racehorses, they did not 'retire to stud' only after their working life was over, as modern racehorses do. For mares, Columella (*r.r.* VI, 28) says they could be bred from between 2 and 10 years, whilst Varro suggested 3 to 10 years (II, 7, 2). These figures (apart from Pliny) are relatively accurate as it is very hard to get an older mare in foal without modern drugs and a stallion begins to lose his fertility during his 20s (Hyland 1990). The principle of improving stock using a different stallion was understood, and a single stallion can influence a deme more quickly than one mare.

Varro (*r.r.* II, 7, 7) states that the foal is born on the tenth day of the twelfth month after conception. This is absolutely correct, as the gestation period of a horse is 335 to 346 days (Clutton-Brock

1992). Without modern drugs, the horse is not the most fertile of animals, only having a fertilisation success rate of about 60% (so even less resulting in live births), indicating why a foal was a very expensive commodity (Hyland 1990). Stallions were fed a high grain diet and first-rate fodder during the mating season. Mares were kept lean as they thought conception was difficult in overweight mares (found to have been true (Hyland 1990)). The working of mares in foal seems to have been a controversial subject, then as now. Virgil suggests they should be worked until the later stages, Varro says no work at all. It may be a question as today, of the size of the breeding establishment. Varro was exclusively breeding a large quantity of horses and mules - this was his job. But many small-scale breeders may have had to use their mares for agricultural work or riding, as today.

By the time of the Empire the Romans certainly knew about and undertook the castration of male horses to produce more amenable animals. Cato mentions geldings in the context of farming, and Varro (II, 7, 15) illustrates the reasons for gelding a horse as follows 'on the one hand, in the army, they want spirited horses, so on the other hand they prefer more docile ones for road service'. Occasionally the military had to geld a colt or stallion that was too unruly. The racing fraternity also preferred stallions, as the more aggressive nature of an entire horse is more suited to this situation, whilst for general riding and draught purposes the more placid nature of a gelding is more appropriate.

According to Strabo and Plato (quoted in Peters 1998) the Romans learnt about the castration of male horses from the Scythians, Sarmatians and Gauls. It was acknowledged that the first two peoples gelded horses to increase their submissiveness. The following statement about the Gallic tribe of the Cantheri shows unequivocally that they castrated their horses '*est enim cantherius equus, cui testiculi amputantur*' (Festus quoted in Peters 1998). At what date the Romans adopted the practice of gelding is unclear, but certainly Varro and Columella were knowledgeable about the procedure. The *Mulomedicina chironis* gives a detailed description of the procedure that is worth quoting in full:

> When you want to castrate an animal you must keep it away from food and drink for a day beforehand. Then lay it down and carefully bind its legs. Make a cut in the middle of the skin of the scrotum about double the size of a coin. Seize the underlying testicle and split the membrane covering it. Draw the testicle to the outside through this hole. Pinch the middle vein with the thumb and stroke the soft covering of the testicle until it tears or cut it off when it is thin. Pull the testicle from top to bottom and cut off the sperm cord near to the sack. In a similar manner remove the other testicle. Clean the testicle covering

> carefully where the openings were made. If the wound becomes irritated or the pus does not drain out, clean it, wash it out and rub ground salt into it. If the cut does not close when left to itself, treat with wood tar and oil spreading the medicine in the opening with the fingers until it is healthy

Apart from the use of anaesthetics and antiseptics, the procedure is essentially the same as that carried out today. Apparently, they even used metal or wooden castration clips to stem the flow of blood (Peters 1998, fig 45). However, no scale is given in the illustration and certainly the larger of these clips appear more like a twitch, a device used to pinch the fleshy part of the horses nose to render it docile. If this instrument were indeed a twitch it could have been used to subdue the horse whilst the castration operation was carried out.

Today, castration is usually carried out when the colt is between six months and two years old, but Aspyrtos (*Corpus hippiatricorum Graecorum*: I, 99, 3, quoted in Peters 1998) suggests that in Roman times it was normal practice to leave this until four years old. The reasons given for this were that the testicles cannot been seen in a foal (modern data suggest they drop at around six months of age) and also the false assumption that castration would prevent the replacement of the milk teeth with permanent ones. The timing of the operation was based on the appearance of the canine teeth (at around four years). In addition it seems likely that waiting until an animal was four years old would allow an assessment of the horse's character and suitability for different areas of work. For instance, a stallion might suit the cavalry if it had the right conformation but if the conformation or temperament were not suited to military activity then castration could take place to tame the temperament and produce a carriage horse. This kind of assessment would be very difficult to make until the animal was fully grown and had been broken in and trained to some degree.

It seems that most horses were stabled only in cold damp weather conditions. This is perhaps borne out by the lack of archaeological evidence for stables. At least there are very few buildings that have been positively identified as such (see section 1.4.1 below). According to written sources stables were constructed in various forms. On Varro's estate the mares each had separate stalls, which were heated by brazier in winter (*r.r.* II, 7, 14). The house of Popidius Secundus, excavated in Pompeii, had stabling of four stalls, with masonry dividers, leading onto a court. At Mondeleia in Syria a stable with mangers and tie rings attached to the wall was found (Hyland 1990). They were also kept in groups, like in American ranch barns, according to Pelagonius in connection with racing stock. These different types are attested to by the fact that they were given different names, an *equile* was a proper stable i.e. a separate accommodation for one horse not tied up, whereas a *stabulum* was a stall where the horses would be tied to the wall at much closer intervals.

Concern for hoof care was also shown in the construction of stabling. Varro (*r.r.* II, 7, 10) recommends that a good floor be laid in all stables to keep the hoof from rotting, and Columella (*r.r.* VI, 30,2) states that it is of prime importance to keep a horse in a dry stable and recommends the use of wooden floors with chaff. Columella (*r.r.* VI, 31) also advises keeping a sick horse on a deep bed of straw or chaff. Bedding for horses in military camps (and elsewhere) is one of the areas for which we have virtually no records. A considerable quantity of bedding would have been required and disposing of such a large quantity of manure each day would have been an arduous task.

The feeding of horses is a bit of balancing act, between giving them enough energy to carry out the tasks required of them and yet not too much to cause them to be unruly. In the Roman world, for favoured equines nutrition was very good, but for those at the lower end of the scale it was a very different story. Obviously the best food for horses is their natural diet of grass. In fact, Columella (*r.r.* VI, 27,2) states that better pasture was required for the noble and mule-breeding stock, preferably well watered and at higher altitude. However, very few areas produce enough grass all year round to give working horses enough nutrients to remain in good health.

For this reason working horses are usually fed supplementary rations in the form of grains and pulses and dried plant fodder. Most of the classical veterinary and agricultural texts give a variety of recipes for horse feed, which have not changed much over time. Grains used were wheat and barley (oats were considered inferior). The grain species grown in Roman times were more varied than today and also had a significantly higher protein content (Reynolds 1979 quoted in Hyland 1990), which meant that less was needed for the horses. This means that the Roman army ration of 5 *librae* of barley (approximately 1.65 kg) per horse per day was probably sufficient, but would be considered too little today.

A variety of pulses was also fed, including horse beans (broad beans), chickpeas, kidney beans and sweet chestnuts. These are all very high in protein and are not generally used in horse feed today but only because most modern horses are not worked hard enough to burn off the energy these feeds give. Cato (*A.C.* XXVII and XXX) and Virgil both state that green foodstuffs included hay, vetch, fenugreek, clover, lucerne and tree leaves, including elm, poplar, oak, fig, willow and broom. Lucerne or alfalfa has a very high nutritional value and originally came from Media, where the Nisean horses were raised. This availability of very nutritious feed may be one reason why these horses were renowned for their size. Good nutrition would have enabled them to reach their full genetic potential (Chapter 2).

The Romans recognised the importance of feeding pregnant and lactating mares well in order to obtain a healthy foal (Varro *r.r.* II, 7, 10) and to give the foal a good start in the first few months of life, as the level and quality of feeding has a direct bearing on the adult size of an animal (see Chapter 2). Varro (*r.r.* II, 7 11-12) also gives instructions for feeding young stock: at five months they should be fed barley-meal ground with bran; as yearlings they should be fed barley and bran until they are weaned at about two years old; from three years they should be fed mixed forage and barley.

The fact that Roman horses seem to be larger than their Iron Age counterparts in many areas of the Empire may in part be due to the extensive trade network enabling most horse owners to obtain first class rations for their animals. This is probably particularly true for the studs breeding equids exclusively for the circus or the military. However, the lot of animals that ended up turning mills at the end of their working lives was probably not very good. Apuleius (*m.m.*) describes in detail the appalling condition of mill beasts, with running sores, mange, coughs and the like. Malnutrition amongst these animals was probably commonplace. It was cheaper to replace an animal that died than to feed it properly.

In addition to food, horses also require a large amount of water each day (donkeys are much more drought tolerant). This can be about 22 litres in normal conditions and more in hot weather. Also horses fed grain and hay rather than grass need more water. For this reason, grazing lands would need to be either close to water or the herds would be driven to water twice a day.

Caring for a horse to maintain its health and usefulness to humans is quite an exacting task. The various elements of this, including feeding and veterinary care, were well understood by the Romans, even if not always applied. Maintaining good hard hooves was of paramount importance, as the old proverb 'no hoof, no horse' was particularly applicable in a time when the horse was vital for every aspect of maintaining the Empire and were not shod with iron horseshoes as they are today. Mares and foals were often driven up into the mountains in the summer to get the foals feet accustomed to rocky conditions and to toughen their hooves.

Lucius (Apuleius *m.m.*) complains that his unshod hooves were worn down to the quick and that he had no shoes to protect his hooves from the hard edges of frozen ruts and broken ice. There are examples of hipposandals from all over the Roman Empire both made of iron (*Solea ferrea*) and rushes (S*olea spartea*). Hipposandals have a flat hoof-shaped base with vertical elements around which thongs or rope were attached, to keep the hipposandal on the hoof. It appears that pack and draught animals were mostly fitted with hipposandals when on difficult terrain, but riding and cavalry horses were not (Peters 1998), perhaps explaining the concern with hard hooves in the texts when choosing cavalry horses. It is interesting to note that nailed horseshoes were probably developed by peoples in northern Europe because of the softer ground they had to ride on. However, they were not generally in use until towards the end of the Empire or afterwards.

Horse grooms and stockmen were expected to know how to treat most minor complaints in horses, a vetinarian only being called in when really necessary. Many works have survived from classical times (Columella, Pelagonius, Vegetius, Varro and in the *Corpus hippiatricorum Graecorum* and the *Mulomedicina Chironis*) dealing in great detail with veterinary matters, suggesting the importance of horses and their health to the Roman population. Many of these contain fascinating remedies for a great variety of illnesses, and practical methods for treating lameness and other injuries. Similar remedies were still in use until the mid-20th century when more scientific methods and drugs were established.

Diseases recognised and treated included colic, coughs and poisonous bites. The classical works also contain general information on good management practices. These include the necessity of daily grooming. Arrian suggests 'massaging the legs and body as it strengthened the legs and rendered the skin supple, removing impurities and imparting lustre to the coat', and Columella (*r.r.* VI, 30, 2) says 'to massage a horse's back … does more good than if you were to provide it most generously with food'. Both of these are in accord with modern thinking. Good horsemanship also meant ensuring that the horses did not fall ill from avoidable excesses. Varro, Columella and Pelagonius all say that most ailments are caused by cold, fatigue, drinking too much when hot after work or working too hard after prolonged idleness. Pelagonius suggests that strained muscles should be treated by swimming the horse in a pond, a treatment that seems to have been ignored until the late 20th century.

Many laws were passed regarding equines. For instance, it was an offence to beat a mare in foal and cause her to miscarry. This was, however, more to do with the fact that horses and mules were an expensive commodity and the laws were to protect property rather than animal rights, as can be seen from the reference to abuse of mill beasts.

Training a young horse is crucial to its future career, and as such was taken very seriously in the Roman world. The early training of young horses was undertaken in much the same way as it is today. Varro (*r.r.* II, 7, 12-13) suggests gradually introducing a three year old horse to a bit and bridle, working without a rider and then the gradually introducing of the weight of a saddle and rider, followed by ridden training. The acknowledged source of much information on the training of horses is Xenophon's The art of horsemanship (*p.h.*) and later authors, including Varro, used it extensively in their own works. In fact this treatise by Xenophon is still considered compulsory reading for those sitting British Horse Society examinations today (Hyland 1990).

Training the young horse on a lunge line and also by long reining are both attested to in literature and art. Aelian mentions running a horse round in circles (lunging) and long reining is seen on tombstones of cavalrymen (Hyland 1990, plate 1). In addition, Tacitus and others mention using a training ring (*gyrus*). This appears to have been a fenced-in circular area much like a modern round pen used for breaking in horses in America. The ridden training would depend on the purpose the horse was intended for, for instance training for the military (see below) would differ considerably from training of racehorses. Columella (*r.r.* VI, 29, 4) states that prospective race horses were broken in at three years old and raced a year later, whilst riding horses were broken at two (the opposite of current practice). Varro (*r.r.* II, 7, 15) commented that the experienced soldier would train his horse one way, the charioteer and circus rider another, while the horse that was used as a pack animal needed to be docile and was usually castrated.

It seems that many horses were sold after the initial breaking in was complete and the new owner would carry out the more specific training. For this reason Varro (*rr* II, 7,2-4), Pelagonius (quoted in Hyland 1990) and Xenophon (*p.h.* VIII, 1) recommend that a person buying a horse should be able to tell its age from the teeth; obviously horse dealers were as unscrupulous then as they are today!

> The horses being said to drop at thirty months first the middle teeth, two upper and as many lower; at the beginning of the fourth year they again cast, this time dropping the same number of those coming next those which they have lost; and the so-called canine teeth begin to grow. At the beginning of the fifth year they again shed two in each jaw in the same way, as at that time the animals has hollow front teeth which fill out in the six year so that in the seventh it usually has a full set of permanent teeth. It is said that there is no way of determining those which are older than this, except that when the teeth become prominent and the brows grey with hollows under them, they determine by looking at him that such a horse is sixteen years old (Varro *r.r.* II, 7,2-4).

The various descriptions of the ageing of horses from the replacement of the incisors are pretty accurate in modern terms, and it is also true when they state that after the age of seven it is very difficult to tell the age accurately. From studies of modern breeds (Peters 1998), the clasiically referenced timing seems closer to that observed in late maturing breeds, such as the Haflinger, rather than the early maturing breeds, such as the Thoroughbred, indicating that the Roman horses may have been of the slower maturing type. The suggestion was made that the wear on the teeth after seven years was more rapid than that observed in modern horses. The fact that these observations were made in the Mediterranean area, where fodder is coarser and dryer, suggests that tooth wear would be hastened under such conditions. Therefore the ageing of teeth from the amount of wear should only be applied to the area and conditions under which the observations were made (Peters 1998).

Military horses

The aspects of the Roman Empire about which most has been written, both contemporaneously and recently, are the emperors and the army. However, the subject of the cavalry, and in particular their horses, forms only a very small part of this vast literature. In addition, the baggage and draught animals, so vital to the operation of the army, are hardly mentioned at all. This is partly to do with the fact that until the later Empire, the cavalry only formed quite a small proportion of the army and was considered second rate. In the 3rd and 4th centuries AD they were more highly rated and formed approximately a third of the army. In Diocletian's time there were 70 cavalry vexillations, each of about 500 men in the eastern part of the Empire alone (Hyland 1990).

Equids in the Roman army fall into two categories, firstly the traction and baggage mules, packhorses and ponies, and secondly the chargers for the various levels in the hierarchy. These included the high ranking officers, legionary cavalry, cavalry *alae*, *cohortes equitatae* and possibly also speedy horses for scouts. Hyland (1990) suggests baggage animals may have varied according to the country in which they were working: eastern and Mediterranean areas using mules and large donkeys whilst more northerly areas may have employed indigenous ponies. Hyland (1990) suggests this would be because mules and donkeys do not do well in wet and cold conditions, whereas the native ponies were more adapted to the conditions in northern Europe. However, information in the literature on the baggage animals is very scarce so there are no clues regarding the likelihood of the above statement, but zooarchaeology may help to answer it (Section 1.4 and Chapters 6 and 7).

Turning to the cavalry horses the art historical sources depicting military horses are particularly numerous. However many of these are politically motivated carvings of Emperors (e.g. the statue of Marcus Aurelius Figure 1.2,) and their achievements (Trajan's column Figure 1.4). Yet many do show some of the characteristics of cavalry horses (Figure 1.6).

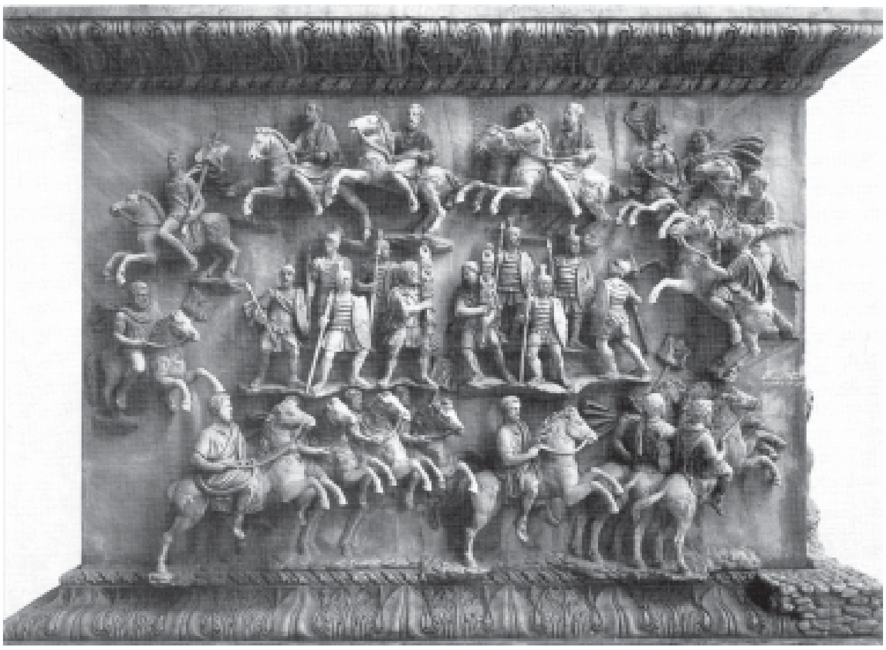

Figure 1.6 Base of Antoninus Pius' column showing cavalry ready for battle (above, from Hyland 1990) and Marcus Aurelius' column showing the Emperor reviewing the horse guard (below, from Speidel 1994).

The cavalry required horses with certain characteristics and these characteristics can be put together from the scraps of information spread throughout numerous texts. The duties a horse had to perform dictated the requirements regarding type, temperament, intelligence, conformation, age, training required and care bestowed. The *Codex Theodosianus* states that horses should 'meet certain requirements as to shape, stature and age' but does not say what these requirements were (Hyland 1990). Cavalry horses tended to be mostly stallions, but the list of remounts in the accounts of the *Cohors XX Palmyrenorum* at Duro Europus in 251 AD clearly indicates mares as well as stallions (Toynbee 1973). This document describes the horses' ages, colours, markings, brands, purchase prices and, in one instance, country of origin. It shows there was no standardisation as long as the animal was fit for the purpose, which included passing a veterinary examination (Hyland 1990).

Virgil (quoted in Hyland 1990: 79) states some of the qualities essential to a charger: 'how the animal from birth picks his feet up high; … is the first to venture on to the highroad; to ford the menacing river; cross bridges; does not shy easily; has a proud carriage; gets excited at the sound of battle and is impatient to engage.' He also says that bay and roan horses were the toughest and white or light coloured horses were worst. This is to some extent true of their feet, as dark coloured hooves are stronger than pale ones. Age requirements seem to have been for animals mostly under seven and preferably 4 to 5 years old. This means they were mature enough to withstand the rigours of training and cavalry life and were also at the height of their physical strength but were young enough to be amenable to training and still be useful for breeding after a few years of service.

As for the size of cavalry horses, Hyland (1990:67) says that:

> 'the size of the horse does not have as great a bearing on its ability to carry weight as would at first appear, but its conformation does, and this also affects its durability … The more compact the animal the greater its load-bearing capacity, and the short stocky breeds that still retain enough refinement to give a smooth ride and achieve sufficient speed are far more suited to the arena of war than the overlarge, lumbering, excessively heavy-fleshed animals … At the other end of the scale ponies would also be unsuitable … For a cavalryman riding without the benefit of a saddle, a pony's gait would be very tiring … it would take too much of the troopers attention merely to stay aboard.'

To clarify this last statement, a pony is not just a small horse: they have different limb and body proportions (Section 1.5) and hence a slightly different way of moving.

Another piece of evidence regarding the size of cavalry horses is the fact that the cavalryman was expected to be able to vault onto his horse easily and cleanly and from either side whilst wearing armour and carrying weapons and also whilst the horse was running (Speidel 1994). Both Arrian and Vegetius state the importance of this and the fact that the cavalrymen practised using a wooden dummy horse (Davies 1969). This implies that the horses were of a size that vaulting onto them was relatively easy. Even though the cavalrymen had to be at least 1730 mm and preferably 1780 mm (from Vegetius), from personal experience this means a horse no bigger than about 1420 mm. The rations of barley and hay suggested for horses in the army (see below) would also be adequate to feed animals of 1220 to 1420 mm, particularly if they were 'good-doers' (Toynbee 1973).

The places that supplied cavalry horses changed through time as the nature and quantity of the cavalry altered. In Caesar's time (1st century BC) the cavalry mainly consisted of the native mounts, which the various auxiliary units brought with them, and specially purchased Spanish and Italian horses for the legionary officers (Hyland 1990). Where possible mounts were recruited along with the cavalrymen, rather than being issued to them later. This reflects the fact that at this time the cavalry was not a major part of the army and almost all cavalrymen were auxiliary troops from annexed and friendly native tribes. The Germanic peoples were particularly admired for their horsemanship, and Tacitus (*ger*.) says this was because they were taught to ride from a very early age and were therefore better than those who had to be taught in adulthood. The wide geographic span of the auxiliary units influenced the types of horses used. Also at this time the cavalry did not fight from horseback; they were used for reconnaissance, sending messages and as back up for the infantry (Clutton-Brock 1992).

In the later Empire, when the numbers of cavalry increased dramatically, military horses were specially bred. Imperial stud farms supplied horses for the army from the time of Emperor Theodosius and probably earlier (White 1970). Where the army got its horses from is not dealt with explicitly in any Roman histories. Many may have come from race horse studs: those that grew too small or too tall, showed no inclination to race, could not be trained in harness, or were just too slow to race. This explanation is borne out by the fact that areas that bred racehorses (Africa and Spain particularly) were also noted as areas from which cavalry mounts were obtained (Hyland 1990). By the time Vegetius wrote in the late 5th century AD, the horses used in the army were mostly those of the barbarian Huns and Burgundians. This reflects the stresses of the Roman Empire at the time and perhaps a shortfall in the supply of purpose bred animals.

The supply of enough horses for the cavalry and enough mules and donkeys for transport of military supplies around the Empire seems to have been a continual problem. This was in spite of measures such as demanding a stock of military horses as part of the regular taxes from North Africa (Clutton-Brock 1992). Hyland (1990: 77) gives a list of the means of acquiring horses, which shows that almost any way possible was used:

1) National contingents that brought their own horses with them
2) Requisition from large landowners

3) Levies on provinces
4) Tribute from client kingdoms
5) Taxes where the whole or part value of a beast was levied on individuals
6) Public services
7) Outright purchase from breeders and/or dealers
8) Imperial/army stud farms
9) Capture of enemy horses.

The cost of purchasing horses for the cavalry varied through time. The price paid by the troopers was fixed, whilst the market price was not, meaning that whilst the cost of a horse remained about half of the soldier's annual pay, the fixed price did not go up with pay increase or inflation. By the late 3rd century AD a horse only cost the soldier about one-seventh of his salary (Speidel 1994). From AD 139 to 251 auxiliary cohorts paid about 125 *denarii* each, whilst the troopers of the *alae,* who were expected to have better horses, paid more (Speidel 1994).

An idea of the numbers of horses (both cavalry mounts and baggage animals) in the army can be worked out from a variety of sources. At Hod Hill (Richmond in Toynbee 1973), a 1st century AD fort with a legionary cohort and a half *ala* of cavalry, it has been estimated that 82 equids were needed. This was worked out from the number of people in a half *ala* of cavalry and a legionary cohort. Thirty troop horses and four officer's remounts were required per *turma*, plus one baggage animal per officer and four per *turma*. The space in the stables (as previously discussed) suggests the presence of 84 animals, which agrees with the calculation. Even a small contingent attached to a *cohors equitata* would present considerable provisioning problems, with 120 plus animals needing to be fed. In Britain in AD122 there were four legions, 12 *alae quingenariae*, one *alae milliaria*, four *cohors equitatae milliariae*, 14 *cohors equitatae quingenariae*. According to the computations of Hyland (1990: 89) a total of 18,503 equids would have been needed for these units to function! This is a considerable number of equids to be fed.

Vegetius tells us that when the army was in camp, the horses were pastured outside when conditions allowed (Peters 1998), with guards posted 24 hours a day to prevent horse rustling. Baggage animals no doubt came under the same system. Meadowland and pasture were set aside for the military use. However, for a third to perhaps a half of the year, in most areas of the Empire, there ws not enough high-grade grass to feed horses adequately, particularly if they had to be kept off it to produce some hay during late spring and early summer. A horse needs around 4.5 kg (10 lb) of hay per day, which means that to feed all the military equines in Britain for 150 days (nearly half the year) it would take 12,500 tonnes of hay. In addition to this, the rations of 1.65 kg (3.5 lb) of grain per horse per day all year round would work out at 11,145 tonnes of grain. Given that crop yields were lower than today (probably about two tonnes per hectare for hay and 1.5 to 2.5 tonnes per hectare for wheat) (Hyland 1990), this would require around 6500 ha of pasture and around 5500 ha of arable land to produce horse fodder for the army alone.

The training of cavalry horses would have been quite a specialised activity and was probably delegated to those cavalrymen who had both an aptitude for the task and experience (Hyland 1990). Training and exercises were undertaken in the open as much as possible, but Vegetius mentions that covered halls were constructed in which the soldiers could carry out their training and exercises even in bad weather. 'In winter they constructed for the cavalry halls of tile or shingles, and halls like basilicas for the infantry' (Davies 1969). The preparation of a cavalry parade ground was described by Arrian 'They choose a site where the exercises are to be held that is flat and they work on it in addition. From the whole level field they demarcate the area in front of the platform into the shape of a square and dig the middle to an equal depth and break up the clods to obtain softness and springiness' (Davies 1969). The last part indicates that the Romans knew that a soft surface would benefit the horses whereas a hard surface would lead to leg injuries and lameness.

Several Classical authors, including Arrian, Onasander and Xenophon (*p.h.*), all state the need for horses to be exercised in jumping over ditches and leaping over walls, rushing up and springing off banks, and also galloping up and down hills and on a slope (Davies 1969). Xenophon (*p.h.*) goes on to explain how to train a horse to jump ditches and walls from scratch and how the rider's position changes when jumping and going up and down hills. The principles are exactly the same as are generally used today to train horses to jump. These kinds of training and exercises would obviously not have taken place on the exercise ground, as they did not contain ditches, walls and hills.

Arrian states 'the commander should … arrange practice battles including pursuits, hand-to-hand struggles, and skirmishes; these manoeuvres should be held on the plains and around the base of hills as far as possible in broken country, as it is impossible to gallop at full speed either uphill or downhill' (Davies 1969). Xenophon (*p.h.*) also indicates that 'It is a correct principle to hold these equestrian exercises in different places and at different times, on occasions making the exercises long, on other occasions short. This is less irksome to the horse than that the exercises should always be in the same place and in the same routine' (Davies 1969). The second piece of advice is one that many modern riders could do with following, as a horse will easily get bored if asked to do the same routine everyday and will probably rebel in some way or get overexcited when asked to do something different.

Vegetius talks about the use of route marches as exercise and training for the troops:

> 'The infantry were ordered to march wearing their armour and equipped with all their weapons to and from the camp for ten (Roman) miles. Similarly the cavalry were also divided into troops, armed in the same way, and travelled the same distance, although in the equestrian exercise from time to time they pursued, from time to time retreated and made ready to charge back again. It was not only in the plains but also in hilly and difficult terrain that both arms of the service were compelled to ascend and descend so that they might never experience an incident while fighting that they had not as trained soldiers learnt by continual practice' (Davies 1969).

Vegetius also says that ' During the summer months every recruit without exception must learn to swim … It is of the greatest advantage that not only the infantry but also the cavalry and even the horses and the soldier's servants should be exercised in swimming, in order that they might not be inexperienced in case of any necessity' (Davies 1969). Horses do swim very well naturally; the problem is training them to go into the water in the first place!

All these exercises would have kept both the horses and riders fit and ready for active service. They would also have accustomed the horses to many unfamiliar situations, so that when they encountered them in a battle situation the horses would not react in an adverse way. All of this is very sound in principle and in practice, showing that the Roman cavalry was as advanced in its warfare as the infantry was.

- ❖ **Research aims.** Did the Romans move large quantities of horses with the army or recruit local stock as they moved? Were the horses used by the military of a particular type of physical appearance?

Circus horses

The circus was the name given to the arena in which chariot racing took place, not to a travelling entertainment group. Therefore circus horses were those that took part in the chariot racing. Occasionally mounted races took place, but the majority of races were for two- or four-horse chariots (*biga* and *quadriga* respectively). Circus horses are perhaps the most often illustrated equids in the Roman period, and often written about. This is perhaps to do with the fact that the Romans (particularly those in major urban centres) were obsessed with racing, on a par with or surpassing modern football fanaticism. However, although there are many accounts of race days and autobiographies of charioteers, there is not nearly as much mention of the horses themselves. Many pictures of chariot horses are seen on mosaics and other decorative items in all areas of the Empire (Figure 1.7), both of individual horses and scenes of racing taking place (Toynbee 1973).

Figure 1.7 Examples of chariot horses depicted on a terracotta lamp, a bronze statuette (both from the British Museum, London website) and a mosaic (Ciurca undated).

The names of racehorses were often recorded on mosaics (Figure 1.8) and in the literature (Toynbee 1973). However, in autobiographies of charioteers only the name of one of the horses in their teams is mentioned. This is perhaps because the lead horse (the horse on the far left hand side when viewed from the chariot) was the one that had to do the most work in cornering and in leading the others during the races, which were run in an anticlockwise direction. Many names relate to the colour of the horse, for instance *Aureus* (golden), *Pupureus* (roan), *Ployeides* (dappled), *Glaucus* (grey), *Maculosus* (piebald) and *Roseus* (bay). Others relate to speed rather than appearance, *Celer* (Swift), *Volucer* (Flyer), *Sagitta* (Arrow), or strength *Adamus* (Cast-iron), and expected triumphs, *Victor*. Many were also named after gods and heroes, such as *Castor*, *Achillles*, *Diomedes* and *Pegasus*. Others were named almost as obscurely as some modern racehorses (Grizzly activewear, Sewmuch character, My legal eagle, Kathakali, etc.)! The list is almost endless and many examples are given in Toynbee (1973).

Figure 1.8 Two mosaics showing racehorses with their names (both from Hyland 1990)

One of the topics most often discussed in the literature is the areas from which good racehorses stemmed. Vegetius indicates that horses for the circus came from Cappodocia, Spain, Sicily and Africa. Gratius Faliscus in the 1st century AD suggests Sicilian and Mycenean horses were good, in addition to the Spanish and African ones. Oppian in the early 3rd century AD says that the Spanish horses were fast but had no endurance, whereas the Libyan (African) horses had good endurance. Sicilian and Cappodocian horses were also fast, whilst Tuscan and Cretan horses were rated but not as highly. Nemisian in the late 3rd century AD rates Cappodocian, Spanish and Greek horses highly. Many racehorse studs were established in Spain, including a number of Imperial studs raising horses for the Emperor's faction in Rome (White 1970).

Therefore in the early Empire African horses dominated the track whilst Cappodocian and, to a lesser extent, Spanish horses were dominant in the later Empire (Hyland 1990). This may have been the result of continual upgrading of the Spanish stock with African blood. This predominance of African horses in racing continues today, as all modern Thoroughbred racehorses can trace their ancestry back to three Arabian stallions imported into Britain in the 18th century AD. Similarly the Romans imported many horses by ship from North Africa (Clutton-Brock 1992).

As in modern Thoroughbred racing, in Roman tims the elite of society owned most of the horses and controlled the occurrence of races. Imperial studs were set up in Spain and Cappadocia to produce chariot horses that ran for the Emperors (White 1970). Often horses from these studs were retired back to them when their racing career was finished and allowed a peaceful retirement out to pasture. This was a far cry from working mills, as many ex-chariot horses ended up doing.

The number of mares needed to keep up the supply of chariot horses was four times that needed for thoroughbred racing today, partly because the mares were not bred every year and also because chariot horses did not have a long working life (White 1970). Chariot horses were nearly always stallions, although the names of a few racing mares are attested to. Their training started at the age of three but they were not raced until four or five years old (Hyland 1990).

A great deal of attention was given to veterinary matters concerning racehorses. Pelagonius' treatise on horse medicine is almost entirely devoted to treating chariot horses, probably because this was his main employment at one stage in his career. Because of the hard surface of the race tracks (to make the chariot wheels run smoothly), chariot horses tended to have a variety of leg problems; they also suffered back and shoulder problems from the strain of turning tight corners at speed (Hyland 1990). Pelagonius devotes several chapters to the cure of these ailments and also to treating eye injuries, bruises and cuts from accidents whilst racing.

Riding and carriage horses

Perhaps because these were considered as the 'common stock' by Columella (*r.r.*), riding and carriage horses are very infrequently mentioned in literary sources. Vegetius mentions that most horses for riding came from Persia, Armenia, Epirote and Sicily. Riding horses had three main purposes, the most obvious of which was getting a person from one place to another. In addition a horse was a status symbol, particularly for city dwellers with some degree of public office. The third purpose was for sport and leisure activities, such as hunting or riding around a country estate. Reasons for the lack of mention of carriage horses include the fact that there were very few carriages around and they only belonged to people of very high social rank (and usually women), and they were more usually drawn by mules (Casson 1994).

Because of the problems with mounted barbarian raiders in the later Empire, owning riding horses was restricted by law to the upper classes, aristocracy, veteran army officers and other wealthy citizens. This was also partly because horses were expensive animals to buy and keep (Casson 1994). Herdsmen were also allowed to own riding horses, but only in areas where rustling was not a problem (Hyland 1990). Apuleius (*m.m.*) mentions that wealthy people had mounting blocks outside their houses and rode 'Thessalian thoroughbreds' and 'Pedigreed Gallic cobs', amongst other types of horse. However, there is no description of what these looked like. Presumably the Thessalian thoroughbreds were the large horses bred in Greece, which were also favoured by the army. The term 'Gallic cob' probably refers to a more heavily built animal such as was described by Caesar when he mentioned Gallic draught horses.

Interestingly, Martial refers to gaited riding horses: 'the small Asturian horse who picked up his hooves in such regular time' apparently had a syncopated gait like the pace or rack, which provides a smoother ride that is ideal when you have no stirrups! The lack of stirrups meant that horses were not that comfortable to ride over long distances (Casson 1994). Pliny the Elder (quoted in Hyland 1990) describes some Spanish horses bred by the Gallic and Asturian tribes as Theldones, which 'do not have the normal gaits but a smooth trot, straightening the near and offside legs alternately from which they are taught to amble'. Many horses and ponies pace naturally and most can be taught to do so (Hyland 1990).

Arrian suggests that the best horses for hunting were those from Scythia and Illyria, which were considered uncouth and ugly (unlike the Thessalian, Sicilian and Peloponnesian horses) but could run after a stag and wear it down. This description implies that these were lean, tough endurance horses. Oppian suggests that stallions were more favoured for hunting as they were faster than mares. Gratius Faliscus suggests that bay or dun horses should be used. This is because horses of these colours tend to have harder hooves, which means they are able to cope better with hunting over any type of ground. Hunting scenes are depicted on mosaics (Toynbee 1973) and some of the most spectacular are from the villa of Piazza Armerina in Sicily (Ciurca undated), and from various buildings in North Africa (Figure 1.9). These show that hunting from horseback was undertaken, and that horses were also used to carry back the dead animals, as Highland ponies still do for stag hunts in Scotland.

Figure 1.9 Two scenes from mosaics showing hare hunting using horses and dogs (above El Jem, Tunisia from a website; below Piazza Armerina, Sicily, Ciurca undated).

Another major use of riding and carriage horses was as the mainstay of the *Cursus publicus:* the state postal and transport system (Casson 1994). Procopius says that about 40 horses were held at each major inn (*mansiones* and *stationes*), with less at the minor inns (*mutationes*). The inns were about 8 to12 miles apart along most major roads in the Empire, with a ratio of two minor to one major inn in most areas. This means that with over 53,000 miles of trunk road and about 4,800 stations, approximately 128,000 horses were in the service of the *Cursus publicus*. Although Procopius suggests these were horses, it is likely that a mistranslation of 'equids' has occurred and that many of these were actually mules, particularly as Casson (1994) refers to similar numbers of animals kept at the major inns *mansiones* but specifies a mixture of horses and mules.

It was expected that these animals would be replaced after only four years of service in the *Cursus publicus* because of the hard usage they received. As well as the public service there was also the private post-horse service, which probably had an almost equal number of horses, mules and oxen. The logistics of supplying this number of animals, and keeping them fed and cared for, was one of the major headaches for the bureaucrats of the Roman Empire, and, as in many such cases, the burden fell to the local citizens (Casson 1994).

- ❖ **Research aims.** Were there differences between the types of horses used by civilians and those of the army? Is there a connection between status/wealth of an individual/ settlement and the type of horses found there?

Horses in ceremonies and religion

Roman ceremonies almost always included some religious element, which is why the two topics have been treated as a single entity. The state kept a number of white horses for use on ceremonial occasions, such as religious feasts and military triumphs. The Emperor usually rode a white horse in triumphal processions because it stood out from other coloured animals. Indeed Trajan rode a white stallion upon his triumphal entry into Rome in AD 99 (Speidel 1994). Many of these may have come from the Imperial studs in Thrace, as these were noted as being huge and white. Those from the Imperial stud at Phrygia were also used in processions (Hyland 1990). Many rulers in later centuries have used white horses on ceremonial occasions for the same reason, including the use of the 'Windsor greys' to pull the Queen's carriage on state occasions in England.

The use of white horses in religious activities in other areas of the Roman Empire may have had something to do with the fact that in the wild a white prey animal is very rare. White animals tend to be killed before reaching adulthood because they have no natural camouflage. Tacitus in his treatise on the Germanic peoples (*Ger*.) gives an account of their use of white horses:

> ..the Germans also have a special method of their own – to try to obtain omens and warnings from horses. These horses are kept at the public expense in the sacred woods

> and groves… they are pure white and undefiled by any toil in the service of man. The priest and the king or the chief of state yoke them to a sacred chariot and walk beside them, taking note of their neighs and snorts. No kind of omen inspires greater trust, not only among the common people, but even among nobles and priests, who think they themselves are but the servants of the gods, whereas horses are privy to the gods' counsels.

In addition to this, horses were sometimes cremated along with their owner if that man was of sufficiently high status and esteem. Burial or cremation of the horse was carried on into the Migration Period in north-west Europe, as evidenced by the many archaeological finds of horse remains, such as those at Sutton-Hoo, UK (O'Connor 1994), and many in Hungary (Bökönyi 1974).

Great importance was also placed on the horse in Thracian culture, as shown by the many depictions of mounted heroes. In Thracian religion the horse played a prominent role, with white horses being sacrificed to the sun. The only votive tablets known from Thrace show depictions of Apollo on horseback (Hyland 1990). Herodotus (VII. 113) says that 'There are other links between Thracian and Persian horses: white horses were also sacred to the Persians and on occasion were sacrificed in propitiation to the Strymon'. These images may be linked to the worship of horses in Greek culture, where horses were considered to be deities in animal form (Peters 1998). Deities were also depicted with certain animals as a form of identification, for instance the god Silenus was always depicted riding on a donkey (Figure 1.10). This idea was carried through into the Roman pantheon where the twins Castor and Pollux (the protectors of Rome) were always depicted with horses (Figure 1.10).

The most obvious religious association between horses and religion is in the worship of the goddess Epona. She was originally an indigenous Celtic goddess, as indicated by her name which is related to the Celtic name for 'horse' (Wells 2001). Representations of Epona always show her either riding a horse or seated between two horses and sometimes with foals (Figure 1.10). Stone carvings, altars and other artefacts dedicated to her have been found in abundance from former Celtic provinces such as Gaul, the Rhineland and Britain, but have been found as far afield as the Danubian provinces and North Africa (Toynbee 1973). She was particularly revered by cavalry soldiers but was also celebrated in Rome, because of her other attributes of fertility and healing (Wells 2001) and her association with the Emperor's horse guard (Speidel 1994).

Although not directly linked to horses, cavalrymen, particularly those from Gaul, worshipped a set of goddesses known as the *Campestres* (Speidel 1994). The *Campestres* looked after cavalrymen whilst they were training rather than in a war situation, so they are associated with training areas rather than in camps (Davies 1969). Archaeological evidence for this practice is outlined below (Section 1.4.)

Figure 1.10 Clockwise from top left: Epona seated between two horses, Epona riding a pony, Castor and Pollux with horses, Silenus riding a donkey (from Speidel 1994, Toynbee 1973, website, Clutton-Brock 1992)

Horse transport

Horses appear to have been frequently transported across the Mediterranean in some numbers, as attested by the fact that African horses were prevalent in chariot racing and frequently used to upgrade Spanish and other demes of horses. Racehorses with the brands of their owners or breeders C. Sabinus and Sorothus are depicted on a mosaic in Barcelona, and both had their studs in Algeria, as evidenced to by other mosaics and inscriptions found there. Hyland (1990) states that it was quite common to move horses in specially constructed horse transport ships. A mosaic from Medeina in Tunisia shows a ship with three racehorses (*Ferox*, *Icarus* and *Cupido*) on board. The type of ship is described by the Latin inscription *Hippago* written underneath, followed by the Greek equivalent (Hyland 1990). A diagram of what a proposed horse transport ship may have looked like is given in Hyland (1990: 98).

Consumption of horsemeat

In most of the ancient literature, the consumption of horsemeat is not mentioned at all because horsemeat was not a normal part of the Roman diet. There are two possible reasons for this: either horsemeat was considered unclean, or there was some religious taboo against the consumption of horsemeat. It could have been a combination of the two, along the lines of the Jewish prohibition of pork consumption. It is presumed (Arbogast *et al.* 2002) that a 'religious' taboo against eating a noble animal reserved for war came from the Greek civilisation to that of Rome. Whatever the reason, it is clear that those who considered themselves Roman only consumed horsemeat in dire emergencies.

Instances of emergency situations are referred to in the literature, such as the wrecking of Germanicus' fleet in the North Sea: ' Some ships went down. Others more numerous, were cast onto remote islands, where men were obliged to eat horses washed up with them, or starved to death' (Tacitus *Ann.* II, 24, quoted in Peters 1998). During the revolt of Civilis 'all normal and emergency rations gave out. They had by now consumed the mules, horses and other animals which a desperate plight compels men to use as food, however unclean and revolting' (Tacitus *Hist.* IV, 60, quoted in Peters 1998).

Other exceptional circumstances included famine, such as encountered by Alexander the Great in India (*Q-C.* IX, 10 quoted in Arbogast *et al.* 2002). Pliny the Elder (*Nat. Hist.* XXVIII, 146, 265, quoted in Arbogast *et al.* 2002) says that it was forbidden to sacrifice horses and also that eating them would give you ulcers and that the meat was unclean. However, it is unclear why horses were regarded as such a repugnant foodstuff when the same man, Pliny the Elder, considered the meat of donkeys and onagers a delicacy.

Indeed there was a specific market for donkey meat in Athens, although it is unclear whether this was for the consumption of donkey meat as part of the normal diet or for the production of a multitude of medical remedies made using products from donkeys. Celse (quoted in Arbogast *et al.* 2002) records that asses milk was supposed to be an antidote for poisons, whilst donkey bones, preserved testicles, foetal membranes and male donkeys' hearts were also used in some medicines to control epileptic fits. Horse parts were apparently not similarly employed in medicinal practices.

1.3.2 Mules

Mules are the result of a cross between a male donkey (jackass) and a female horse (mare) (as discussed below). A hinny is a cross between a male horse (stallion) and a female donkey (jenny). It is considered that the mule is generally stronger and more robust than a hinny. The reason for this is because the mule's dam (the mare) is larger than its sire (the jackass). When the cross is the other way, the resulting hinny will not be much larger than the donkey dam, because the size of the dam limits the size of the foetus (Clutton-Brock 1992). During the Roman period it seems that mules were bred more frequently than the hinny, as most of the Classical sources that mention hybrid equids are concerned with mules. Whilst Varro (*r.r.* II, 8, 6) mentions hinnies, in so far as to identify the parent animals and describe their appearance ('smaller than the mules, with ears like a horse but with mane and tail like those of an ass'), he then dismisses them as inferior to mules. Columella (*r.r.* VI, 38, 5) concurs with both the description and the assertion that hinnies are inferior to mules.

Varro (*r.r.* II, 8, 5) states that mules drew all vehicles on the road (see Figure 1.11 for examples). This may be an exaggeration but implies that a great many mules were bred and used. Clutton-Brock (1992) suggests that mules became the essential means of transport in the ancient world because it was found that the strong hybrids produced by breeding a male donkey with a female horse were the most powerful and resilient baggage animals for both peace and war. As was discussed briefly in the sections above on military and riding horses, mules were the primary baggage and draught animal of both the Roman army and the civilian *Cursus publicus*. Mules were an essential part of life to the Romans, being used for riding, ploughing, drawing carts and carrying baggage. Mules are seen drawing carts on coins, tombstones, other carvings and mosaics. Draught mules are depicted (Figure 1.4) on Trajan's and Marcus' columns and pack mules are also shown in military contexts on Trajan's column (Toynbee 1973). Mules were also used to bring home the spoils of the hunt.

Mules were not considered second-rate riding animals but could be difficult to ride (Figure 1.11). Martial mentions several types of mule, and a well-bred mule could set the purchaser back the price of a house. A spirited mule could give a lively ride to a gentleman of the upper classes. For timid riders who feared a lofty steed there was a breed of dwarf mule (Hyland 1990). The best mules were probably small horse size (14 to 15 hh), as the largest donkeys and mares were used and hybrid vigour would make them still larger.

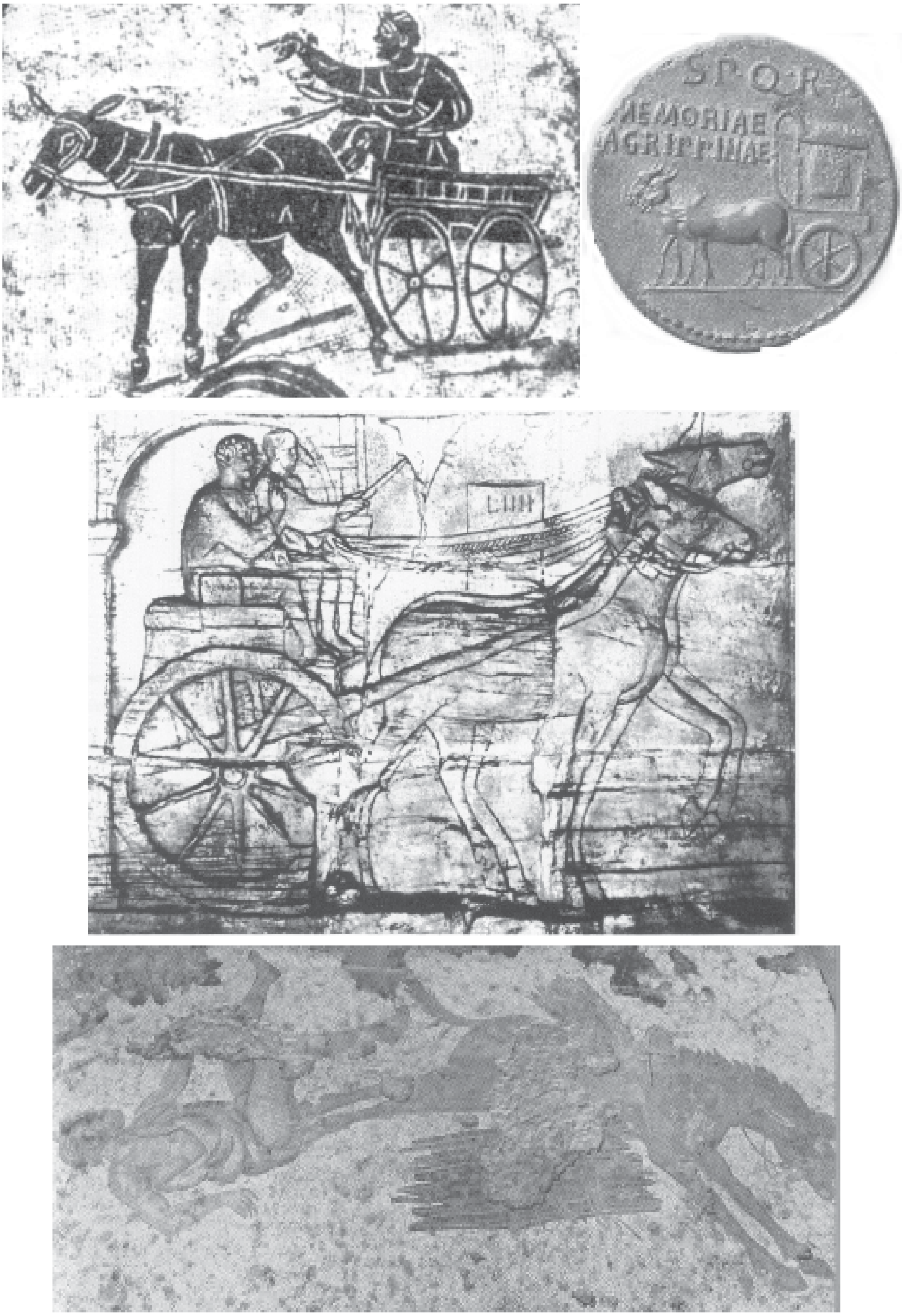

Figure 1.11. Clockwise from top left: two-wheeled mule cart depicted on a mosaic, coin showing mule-drawn funeral carriages of the Empress Agrippina, carved relief of a mule-drawn carriage and a mosaic showing a mule throwing its rider! (top left from a website, others from Toynbee 1973).

Much of what has been said above regarding the breeding and care of horses also applies to mules, but are a few extra points that are worth making regarding mules in the Roman Empire. Varro owned a mule-breeding stud at Reate in Italy, so his information on the subject should be accurate. He says that mule breeding was very profitable but that it could cost 3 to 4,000 sesterces for a good jackass to breed from (*r.r.* II, 8, 3). This shows something of the economic importance of mules (or an unlikely rarity of donkeys). Varro (*r.r.* II, 8, 3) suggests that where there is no jackass available that has been reared on a mare (see below), one as handsome and heavy as possible should be bought from a good breeding area such as Reate in Italy or Arcadia in Greece.

Varro (*r.r.* II, 8, 2) also says that jackass foals destined to be used to breed mules were taken from their mother and reared on surrogate mares. This was because a mare's milk is more nutritious than jenny's, so the donkey foal would grow larger. Columella (*r.r.* VI, 37, 8) also writes about this practice but says that the reason was so that the foal became accustomed to horse behaviour patterns, so that it would respond to a mare in oestrus. Both explanations are rational and probably the combination worked in the jackass' favour. Xenophon (*P. h.* V, 8) claims that jackasses will not mate with mares because they have long manes, and that mares destined to breed mules must have their manes cut off. This erroneous belief has been perpetuated in other classical works and even in the 19th century AD was still being carried out (Peters 1998). Columella (*r.r.* VI, 36) suggests that a jackass reluctant to mate with a mare should be presented with a jenny first, which is then substituted for the mare when the jackass is aroused.

On the subject of choosing a jackass and mares for breeding mules, Columella is most specific, saying that they should be chosen with great care or the resulting offspring will be a failure. The mares (*r.r.* VI, 36, 2) should be 'big and handsome and well able to endure toil' so that she will impart both her good physical qualities and natural disposition to the mule foal. As for the jackass (*r.r.* VI, 36, 3), he says that good ones are hard to find, and often a good-looking jackass will produce poor offspring and *vice versa*, so choosing is difficult. Temperament is also important, and whilst a jackass of 'fierce passions' is desirable, sometimes he has to be harnessed to a mill to work off the energy in order to be manageable (*r.r.* VI, 37). Whilst both Columella and Varro indicated that wild jackasses could be used for breeding mules because of their large size, the resulting offspring were considered too unruly and a second generation jackass was then preferable. This was because it showed the spirit and agility of the grandsire (wild ass) and the form and tameness of the sire (Domestic x wild ass) (Peters 1998).

Mares used to breed mules were only put into foal every other year and only bred between the ages of 4 and 10 years, thereby producing only five mule foals each (Columella *r.r.* VI, 36, 2), another reason for the high cost of mules. Columella also indicates that the gestation period for a mare breeding a mule is slightly longer than usual, at just over a year (corroborated by with modern veterinary data; Clutton-Brock 1992), and that the foaling is often difficult. Jackasses should only be used for breeding mules after they are three years old (Columella *r.r.*). In order that a jackass could mate with a larger mare, the Romans built a ramp with cross bars, onto which the mare was tied at the lower end so that the donkey (who was of smaller stature) could walk up the ramp to mate (Columella *r.r.* VI, 37, 10).

Mule foals were driven into mountainous regions in the summer to harden their hooves (Varro *r.r.* II, 8, 5). This was another economic consideration, as those with hard hooves would last longer unshod when working on hard road surfaces. Apparently male mules were better at carrying pack-saddles but female mules were more nimble (Columella *r.r.* VI, 37, 11) and both 'step out well on a journey' and could be used for ploughing on light soil.

The appearance of the mules was also of concern to Columella (*r.r.* VI, 37, 6-7), who suggests that they should have 'ample stature, a strong neck and broad flanks, a vast and muscular chest, brawny thighs, solid legs and a black or spotted coat'. He seems to suggest that mules of other colours were inferior, particularly if they were mouse-coloured like donkeys.

1.3.3 Donkeys

The wild ancestors of the domestic donkey (*Equus asinus*) are the African asses. However, it is unclear whether one or more of the subspecies of *Equus africanus* contributed to the domestic donkeys of Roman times and today. Clutton-Brock (1999) argues that it is likely that at least two if not three subspecies were used. The Algerian wild ass *E. africanus atlanticus* (now extinct) has been identified on Roman mosaics from North Africa and was probably exterminated by the Romans. It may have been imported into Europe and used to breed from by the Romans. The mosaics depict it as having strongly marked long shoulder stripe and bars on the legs. *Equus africanus africanus,* the Nubian wild ass, has a clearly defined back stripe and a short but clear shoulder stripe but no bands on the legs. It is not possible to say which subspecies contributed most to present domestic donkeys; the Nubian ass was probably domesticated by the Egyptians, whilst it is probable that the Romans imported the Algerian ass. The Somali wild ass *E. africanus somaliensis* is quite large (can be over 1400 mm withers height). It does not have many much shoulder and back stripes but has very clear leg bars. Because of its size it seems likely that the Romans would have used this ass to breed bigger domestic donkeys and hence bigger mules. If the list of animals used in the spectacles in Rome is anything to go by, then the Roman Empire certainly accessed the Sub-Saharan wildlife so could have had access to these asses.

The domestic donkey is in some ways the 'Skoda' of the equine world: the butt of many unfounded jokes. This was true even in the Roman period as the novel 'The Golden Ass', written by Apuleius (*m.m.*), makes clear. In this book Lucius is accidentally turned into an donkey and the story relates all the trials and tribulations these beasts had to endure. Mostly the donkey's lot in life was a poor one, full of hard work and little reward. Cato (quoted in Hyland 1990) places these animals firmly in a niche as the beast of all work on a farm raising olives. The donkeys were used for rotating the mill for crushing the fruit, as well as hauling olives to the press, carting manure and so on. Donkeys could also be used for many other farm duties, including ploughing on light soil. Many of these activities are depicted on a mosaic from the Villa of the Laberii at Oudna in Tunisia (Figure 1.12).

Figure 1.12. Scenes of daily life on a large farm from a mosaic in Oudna, Tunisia (above, from a website), and a humerous depiction of a donkey refusing food from a mosaic in Istanbul, Turkey (below, from Toynbee 1973).

Varro (*r.r.* II, 6, 5) states they were used as pack animals carrying panniers to carry oil, wine, grain and other merchandise. A donkey's load was calculated as 100 kg (225 lb), a mule as nearly twice that (Hyland 1990). Donkeys were also used for traction, ploughing in areas of light soil and more particularly turning mills (White 1970). Varro (*r.r.* II,VI, 5) suggests that herds of donkeys were not kept by estates, only the few required for work, and that traders assembled their own herds for pack trains as they needed them.

Mosaics often depict donkeys working mills or being beaten along under enormous loads. The crush of pack donkeys and mules in cities caused traffic jams, and tremendous pollution of road surfaces. Donkeys also contributed to noise pollution because they are very vocal, unlike horses (Hyland 1990).

Columella (*r.r.* VII, 1, 1-3) reiterates most of the information above, suggesting that as a beast of all work the donkey was second to none, not only because it can carry surprisingly large loads for its size but also because it can thrive on very little fodder and is rarely affected by disease. He particularly mentions that it can feed on leaves, thorns, twigs and chaff as well as conventional fodder. For these reasons, donkeys were considered to be one of the most significant working animals in the Mediterranean area (Peters 1998).

Ordinary donkeys were bred in large numbers all over the Empire, but on a small scale, unlike the vast mule studs of Varro. The best donkeys, used for breeding mules, came from the areas renowned for mule breeding, such as Reate in Italy (see section on mules above). Perhaps the mule-breeding studs also bred high-quality donkeys for their own use. It is mentioned in Columella (*r.r.* VII, 1) that donkeys bred in Arcadia were cheap and common in his times, whereas they were considered quite highly in Varro's time as he felt it quite an achievement to sell a jackass to the Arcadians. Small donkey demes were said to have come from Illyria, Thrace and Epeiros (Peters 1998).

On the subject of building up a breeding, herd Varro (*r.r.* II, 6, 2) suggests that animals of the correct age should be bought so that they have the maximum breeding life left in them (presumably around three years old, although this is not specified). They should be 'sturdy, sound in all parts, full bodies, and of good stock' and, as both parents contribute to the quality of the offspring, both should be chosen with care (*r.r.* II, 6, 4). This seems to be in contrast to the breeding of horses, where the stallion was considered to impart most of the quality to the foal. The pregnant jennies were not worked so that their offspring did not suffer. The young were not weaned until a year old, and then only partially. At three years old they were trained for whatever purpose was desired.

The treatment of illnesses in donkeys and mules seems to have been carried out in much the same way as for those of horses (Peters 1998) with a few exceptions noted by Columella (*r.r.* VI, 38). The castration of donkeys seems to have been carried out earlier in the animal's life and following a different method than that used for horses. Apsyrtos (*C .h.G.* I, 99, 5, quoted in Peters 1998) indicates that donkeys were castrated at two years old by 'binding the testicles with linen, hold them firmly and cut obliquely. With this method no inflammation follows if the cut is treated with fire irons'. Perhaps the earlier age of castration, in relation to horses, reflects the use to which these animals were put. Only those destined for breeding would to be kept entire, as the use of donkeys as pack and draught animals meant they needed to be as tractable as possible. The earlier castration is undertaken, the less male behavioural characteristics have developed and the more docile the animal becomes. By extrapolation it is suggested here that mules may also have been castrated early for the same reasons.

1.4 Roman equids in archaeology and zooarchaeology

Archaeology can be defined as the study of the human past and of human behaviour through the collection, analysis and interpretation of the material remains left by those people (Wells 2001). Archaeology can, therefore, study periods from which no written records exist and can examine aspects of everyday life that are not mentioned in literature sources. The sub-discipline of zooarchaeology, the study of faunal remains from archaeological sites, started towards the end of the 19th century AD with the identification of animal bones together with some efforts to quantify the animals represented and find out what size they were. However, most advances in terms of the quantity and quality of information being gained from faunal remains have been made in the last 35 years. There are still wide discrepancies in the quality of information available in bone reports from different countries, and as a result of this much information has been lost.

Within the area covered by the Roman Empire, there is a long tradition of detailed bone reports from northern, central and eastern Europe in particular that allow comparison of sites and study of the socio-economic implications of the data. Unfortunately the core areas of the Empire around the Mediterranean are very poorly represented in the zooarchaeological literature for the Roman period, even though these areas have a good tradition of faunal analysis from earlier period sites.

There are many reports on bone assemblages from Roman sites that include small quantities of information on the equids, which will be used for the main data collection exercise of this thesis (see Chapter 5). In addition, there are a number of synthetic studies that bring together the information available in the site reports, mostly concentrating on particular regions. These include the extensive studies of Peters (1998) on the Roman animals of the Upper Rhineland area, Bökönyi's (1974) detailed analysis of animals in central and eastern Europe, including those of the Roman period, and the study of Arbogast *et al*. (2002) on horses in France through time. There are also smaller studies, such as those of Lauwerier (1988), and Lauwerier and Robeerst (2001) on Roman horses in the Netherlands, and the study undertaken by Luff (1982) for Roman Britain and the near continent that contain relevaent information. The following information was gleaned from the synthetic and smaller surveys and is presented under similar topic headings to the art and literature information presented in Section 1.3.

1.4.1 Mules and donkeys

Mules and donkeys are not often mentioned in a positive way in the zooarchaeological literature, as they are not often identified. Bökönyi (1974) states that donkeys were used by the Persians against the Scythians in the early 1st millenium BC, and that they were adopted by the Greeks in the last few centuries BC. According to Aristotle (*Hist.an*. VIII 162, quoted in Bökönyi 1974) the 2nd century BC asses in Illyria, Thracia and Eprirus were small. Bökönyi (1974) also mentions that there is zooarchaeological evidence that there were many donkeys in the Greek colonies around the Black Sea. In the Roman period Bökönyi states that asses were found at Cambodunum (Bavaria), Wurttemberg, Paris and Heidelberg as well as at Tac in Hungary.

According to Homer (*Iliad*, XXIV, 278, quoted in Bökönyi 1974), mules were first bred by the Mysians. Bökönyi (1974) suggests that mules were present in south-eastern Europe by the 7th century BC and were included in the Greek Olympic games during the 6th century BC. Mule breeding spread to central Europe via the Greek colonies on the Black Sea. Bökönyi (1974) states that these mules were quite big, i.e. similar in size to horses (although no actual figures are given). He also mentions that no mule bones had been found (or at least been identified) in Roman deposits from central Europe.

Peters (1998) states that mules are supposed to have arrived into the Rhine Danube area with the Roman army, and that this is attested to by the presence of five skeletons at Dangstetten (data from which were unfortunately not available for this study) that are presumed to be connected to the Alpine campaign of AD 15. A single mule, assumed to be a victim of battle of Varus in AD 9, was recovered from Kalkriese and must have been a pack animal with the army. Peters (1998) states that up until 1998 there is very little proof of the presence of mules other than these six, although a few scattered individuals are known. This is in contrast to the literature and art sources, where their stated great importance to the army suggests they were very numerous. Peters (1998) stresses that the problem lies in the fact that mules are only trivially osteologically different from horses. If the data on the numbers of mules from the recently researched equid skeletons from Weißenburg are anything to go by, there is a ratio of five horses to each mule indicating that many mules are 'missing' from other sites. The question of whether mules were bred in the western Rhine Danube province is not clearly answered, but the lack of donkeys may suggest that they were not bred there.

Therefore, whilst the remains of donkeys and mules have been found in small numbers on archaeological sites in many parts of the Empire, including Britain (Armitage and Chapman 1979) and Germany (von den Driesch and Cartajena 2001), there are vast numbers of mules in particular unaccounted for in the archaeological record.

- ❖ **Reasearch aim.** Because of the discrepancy between the contemporaneous and zooarchaeological literature it is imperative to find out whether the existing methodologies used by the zooarchaeologists effectively separate horses, donkeys and their hybrids. If not, can a methodology be constructed to identify the equids categorically, so that material that has hitherto been identified as 'horse' can be re-evaluated?

1.4.2 Horses

Appearance, size and shape

For Britain as a whole there have not been any extensive studies of the size and shape of Roman horses. In her study, Luff (1982) includes some information, mostly from south-eastern Britain. However, one problem with this work is that the 'Hands' measurement has been wrongly used (see Section 1.5.5) and no metric equivalents are quoted, therefore it is difficult to give figures for the estimated mean withers heights presented in that study. Relative sizes can be given, for instance in most cases the Roman horses are larger than the preceding Iron Age ones, with the exception of a few individuals.The studies of Johnstone (1996) and Johnstone and Albarella (2002) also indicate clear differences in height between pre- and post-(Roman)conquest horses in Britain.

Luff (1982) suggests that these larger individuals could be geldings, as the delayed epiphyseal fusion and hence elongated growth period could cause them to be taller. However, it is not mentioned whether these bones were also more slender, which might be another indicator of gelding. Luff (1982) also states that larger horses were present on civilian sites than on military ones, and again the suggestion is that this is perhaps as a result of stallions being used by army and geldings by the *Cursus Publicus* (as stated in Varro *r.r.* II, 7, 15). Luff does point out that not much work has been carried out on the effects of gelding on bone growth in horses, so these suggestions cannot be substantiated (see also Chapter 2).

Hyland (1990) suggests that the range of size of Roman horses was from about 1380 mm to 1540 mm, with a few smaller outliers (confirmed for Roman Britain in Johnstone 1996). Horses of this size were sufficiently large to operate efficiently and had smoother gaits than the small ponies. Modern horse breeds that cover this range include the Arabian, Quarter-horse and Morgan (which can be bigger), and larger ponies such as the Dales, Highland, Connemara, New Forest, Camargue and Haflinger. As discussed earlier, a more robust horse was preferred by the Romans, more like the pony breeds rather than the horses mentioned above.

Moving across the English Channel to look at the horses of France, the extensive study of Arbogast *et al*. (2002) gives quite detailed information on the heights of both Iron Age and Roman horses in Gaul. The mid- to late Iron Age horses were very small in comparison with all periods, both preceding and following. They were approximately 50 mm shorter on average, and some individuals were only about 1000 mm at the withers. These animals were also classed as 'gracile' or 'below average' based on metapodial shape indices (Arbogast *et al*. 2002). Caesar (*B.G.*) recounts the gifting of horses to a Gallic king prior to conquest of the area, and the granting of permission to import more to use for breeding purposes to upgrade the native stock. These literature sources are borne out by the study of the horse bones from Gaul, which reveal that whilst most were from small individuals there were a few large, probably imported, animals.

The annexation of Gaul into the Roman Empire by Augustus (late 1st century BC), sees a marked increase in the size of the horses (Arbogast *et al*.(2002). Whilst small individuals arestill present, thereare vastly greater numbers of larger ones. However, the horses from one of the 1st century AD sites, Vertault, are probably not representative of the period because they are all male individuals and were sacrificial victims. In contrast the 2nd to 3rd centuries AD are better represented, with many more animals of middle height and fewer of the smallest individuals. There are also fewer 'gracile to average' individuals and many more robust ones, based on the metapodial indices. In late Roman times (4th to 5th centuries AD) there is a further reduction in numbers of the small individuals and a lifting of the lower end of the range and a corresponding increase in numbers but not height at the top end of the range (Arbogast *et al*. 2002).

It is difficult to trace changes in morphology of horses from the Iron Age to Roman periods in Gaul, mostly as a result of the lack of whole skeletons from Iron Age Gaul. In the Roman period it is most likely that a great diversity of forms of horses existed to suit different types of employment, for instance those for racing and hunting would have to be fast and have an aptitude for going in all types of terrain, respectively. The principal concern for the military horses was size, and this was achieved by importing Scythian-type horses via the Greeks, Persians and Spanish. Large horses permitted the army to conquer areas, but they always needed remounts, so large horses were imported to introduce selective breeding to Gallic peoples and supply the army with horses. This could be expected to impose a uniformity of size and shape across Gaul, but the size in particular differs between sites (Arbogast *et al*. 2002).

Moving across to the Netherlands there are two studies of relevance, the first (Lauwerier 1988) concerning the animals of the eastern river area (Rhine Delta) in Roman times, and the second (Lauwerier and Robeerst 2001) specifically concerning horses. From the first study there are a few general points tto be noted, but all the withers heights data from pre-Roman, Roman and native material have been combined to give an èaverage of 1434 mm (range 1240 to 1630 mm). It is stated (Lauwerier 1988) that the bones from military and villa sites gave the tallest values in the withers height calculations. It is also stated (Lauwerier 1988) that there was no increase in size through the Roman period, but there is no mention of the Iron Age/Roman transition period. In addition, the Roman eastern river area horses seem quite tall, in comparison with the native settlement at Rijswijk (1314 mm), and the Roman sites slightly further away at Valkenbrug (1406 mm) and Xanten (1375 mm).

The second study (Lauwerier and Robeerst 2001) uses the withers heights in a much more instructive way to highlight a number of differences between settlement type. The horses from the native settlements beyond the *Limes* boundary to the North are smaller (mean 1320 mm withers height) than those of villa and military settlements within the Roman Empire (1440 and 1420 mm respectively). Also rural settlements inside the *Limes* produced horses with a mean height between the two extremes and also a larger range of sizes. No trace of any exchange of large breeding animals to sites beyond the *Limes* could be found.

The authors (Lauwerier 1988; Lauwerier and Robeerst 2001) suggest that horse producers on the rural sites inside the *Limes* could have offered a wide range of sizes of horses as they had both native and Roman stock available to breed from. The army as consumer took the largest (either requisitioned or bought), as these best suited their purpose; therefore the rural producers used what was left. Villa sites also produced large horses and it is suggested that this fits with their more Romanised and wealthier status. The theory is put forward that the largest animals (over 1600 mm) could have come from renowned horse breeding areas such as Pannonia (Hungary).

Moving further up the Rhine, Peters' (1998) survey of the Rhine and Danube areas (mostly Germany, Austria and Switzerland) includes many analyses of the measurement data of the horses from late Iron Age, Roman and native settlements. In general the size of the horses appears to decrease from the early to late La Tène periods and then increases again in the Roman period, as was the pattern observed in the Gallic material. In the late La Tène period the mean withers height is only 1210 mm, similar to that for Gaul. Peters (1998) explains this lack of stature by suggesting that the same pastures were used constantly (overgrazing), that food was scarce in winter and that there was a general lack of interest in or knowledge of selective breeding amongst the Germanic peoples. This appears to contradict the references to the Germanic tribes' good horsemanship in the Classical sources; however, an ability to ride a horse well is not necessarily associated with an interest in breeding or raising horses.

As in Gaul, isolated occurrences of large horses north of the Alps in pre-Roman times are found, such as at the Manching oppidum site (Boessneck *et al*. 1971). However, these occurrences are once again all from sites known to have had contact with the Romans, so they could be traded goods, war booty or rewards for service. It is not clear if these large imports were crossed with small native ponies at this time or only after the Roman conquest of the area.

From early Imperial times, the larger horses are found in numbers on sites all over the western Rhine-Danube province (Peters 1998), suggesting that these animals were, at least initially, being imported, and then they were used for improving the native stock to supply the army with horses for initial conquest wars and then to secure the *Limes*. The mean withers height for the early Roman horses in the Rhine-Danube area is 1370 mm (Peters 1998). This figure is some 100 mm larger than the mean for horses from sites in Germany byond the *Limes* frontier of the Empire. Within the Empire animals under 1250 mm seem to be rare in the early Roman period and those that do exist are from sites with known contacts outside the Empire, either in border areas or along major trade routes. This is similar to the findings from Gaul (Arbogast *et al*. 2002).

In the mid-Roman period in the Rhineland the withers heights range from 1160 to 1530 mm, with a mean of 1390 mm based on just the metacarpals. If other bones are used, some larger individuals (i.e. over 1600 mm) are detected (Peters 1998). Therefore, most of the Roman 'horses' were in fact mid-large ponies (1200-1473 mm) and small horses (1473-1600 mm). Peters (1998) mentions at this point that the mules so far identified are generally taller that the horses, with a mean withers height of 1530 mm.

Peters (1998) also mentions some problems associated with the limb proportions of the studied horses. In the withers height calculations, the values estimated from the tibiae and radii tended to come out larger than from the other bones, so it was concluded that perhaps this was because the calculation factors were derived from modern horses which might not have same limb proportions as pre- and early historic ones. Peters (1998) does not, however, connect this difference in limb proportions amongst the 'equids' to problems with the identification of mule bones, even though he mentions at a later stage that mules do have different limb proportions.

The Iron Age Germanic tradition of sacrificing horses means that there are plenty of whole skeletons from this period to look at differences in limb proportions and build, but because of the process of Romanisation this practice died out, with the result thatthere are many fewer whole skeletons from the Roman period. However, the skeletons that are present show that there is little difference in proportions between the periods and that overall size does not affect these proportions.

In terms of build, positive allometric changes (i.e. as bone length increases, the breadth increases both absolutely **and** relatively) have been noted (Peters 1998) between the Iron Age and Roman horses, and also between native and Roman horses, but these were not statistically significant differences. Peters (1998) does note that the differences observed in the shape index results could be the result of genetic variability, but could also be a reflection of those individuals that were affected by nutritional deprivation. The suggestion is made that the Roman horses were more slender than those of the Iron Age, but Peters (1998) then goes on to suggest that this may be a product of the problem of mule identification, as the mules are much more slender overall. Therefore the results of build analyses must be questioned where identifications have not even been attempted.

Peters (1998) uses the heights and shape indices from various modern breeds as comparisons for the archaeological material. Modern 'walking' horses have a height range of 1550-1710 mm, and a mean shape index of 18.39 (range 16-21); thoroughbred racehorses have comparable withers heights but a more slender mean index of 15.89 (range 12-19) and the Belgian Coldblood (again of similar height) has a mean index of 21.6. The Roman horse bones mostly have a shape index of greater than 15.99 so are all relatively robustly built. From this evidence it suggested that the Roman horses were mostly more robust than the horses from both the preceding Iron Age and contemporaneous native settlements.

Moving further down the Danube and into eastern Europe, an extensive study of the animal remains found in sites from this region was undertaken by Bökönyi (1974). Information from Bökönyi (1974) is presented chronologically below, so discussion of the Iron Age horses of the area comes first. It is argued that there were two types of horse in the Iron Age, which possibly had different origins. The first group consisted of large and more robust horses, which have been termed the 'eastern group' whose remains are mostly found in the lower Danube region (Hungary, Romania, etc.) and a smaller 'western group' found mainly on sites in the upper Danube area (Austria, Switzerland and southern Germany). The eastern group has a mean withers height of 1355.2 mm, a metacarpal index of 15.24 and a metatarsal index of 11.59.

It is argued (Bökönyi 1974) that the Greek and Persian horses were derived from the eastern stock type as it is known that these peoples imported Scythian animals, the remains of which show that they were large and robust. These horses then influenced the Roman horses by being imported from Greece and Persia, and bred in whatever combination was required to breed horses for specific purposes. Large bodied animals with taller withers heights are found on many military sites and villas in the Roman period, but many rural settlements in the Danube region only have smaller horses. The Roman horses have a mean withers height of 1408.3 mm, a metacarpal shaft index of 15.05 and a metatarsal index of 11.91.

In discussion of the post-Roman migration period horse remains, Bökönyi (1974) talks about the sex of individuals, which is also relevant to the remains from Iron Age and Roman periods. He suggests separating mares and stallions using the presence of well-developed canines, but also adds caution as it is suggested, from modern data, that up to 22% of mares also have canines, although not usually well developed ones. It is also noted that a proportion of those individuals with well developed canines also had very long and slender metapodials which, it is suggested, could be the remains of geldings (Bökönyi 1974). It is suggested that this could be true if the metacarpal length is more than 23% of total length of forelimb with a shaft slenderness index of below 14.5 and if the metatarsal length is greater than 26.7% of the total hindlimb length with an index below 11.5%. This may be a good starting place but can obviously only be used where the total limb lengths are known (i.e. for whole skeletons or articulated limbs). In addition the possibility that the slenderness could be caused by malnutrition during growth or that these individuals could be mules is not discussed.

From the above summaries it can be seen that quite a lot of information is available on the size and shape of Roman horses across Europ,e but that there are a number of problems associated with material that cannot definitely be attributed to species, in particular, there are problems with assessing the size of the mules that could be contributing to the upper end of the withers height ranges and the lower end of the shaft slenderness figures.

- **Research aim.** If the separation of species (outlined in previous research aim) is achieved, then it will be possible to address the question of size and shape for identified bones separately, allowing a more accurate picture of the appearance of these animals to be constructed.

Horse care, training and hunting

One piece of evidence regarding the care of horses that can be deduced from archaeological sites, comprises the size and construction of stables. Indirectly this can give some idea of the size of the horses that occupied the stables. As mentioned above (Section 1.3.1) there were at least three types of stabling arrangement: loose boxes, with a single untied horse occupying each; stalls, with one or more animals tied to a wall between each partition; and the barn situation, with many animals loose in a larger area. The last of these allows the largest number of animals to be kept in the smallest space but is obviously unsuited to a mixed sex herd. The next best solution is the stall arrangement, where a few animals that get along together can be tied up in close proximity. The first arrangement is the way most horses are kept today, when space is not an issue, and is ideal for foaling mares and keeping stallions separate in a stud situation. In marching camps the military would probably have used picket lines: two stakes with a rope attached between them to which the horse could be tied on either side.

Unfortunately there are very few sites where excavated buildings have been positively identified as stables. Some of these are military sites, others civilian, but many excavated buildings cannot be attributed to any particular use. The difficulties of identifying a barn in which livestock were kept from any other type of barn, let alone where horses as opposed to other animals were kept, are obvious. In other cases buildings that once had partition walls, which could be used to identify stables, may not be able to yield such information as the partitions could easily have been constructed of perishable materials that do notpreserve.

Sites with buildings that have been identified as stables include Hod Hill (UK) (quoted in Toynbee 1973), Brough-on-Noe and The Lunt (UK) and Dormagen and Krefeld (Germany) (all quoted in Hyland 1990). These are all very different in plan and seem to have a small number of internal partitions, perhaps indicating that the horses were tied to the walls in a stall arrangement rather than in individual stables. This is unsurprising given the fact that space was usually at a premium but separation of the sexes would still have ben necessary. At Dormagen the areas between the

partitions measure 3.5 m square, which is the size of a modern loose box for one horse, however three horses who got on well together could be tethered to one wall.
At Hod Hill, a 1st century AD fort with a legionary cohort and a half *ala* of cavalry, the stables were excavated thoroughly (Richmond quoted in Toynbee 1973). Two types of stabling were uncovered, the first was partitioned into spaces 3.35 m x 3.65 m, the second into spaces 3.35 m x 5.5 m. The first type would allow three horses to be tethered to either side of the cross wall with a 1.8 m alley behind each group, in the second there would be two rows of three horses tethered to opposite walls with a 1.8 m alley between the rows.

These stables had a natural chalk floor in which the hoof scrapes were visible. The front hooves scraped about 45 cm from the cross wall and the hind ones about 90 cm behind the front ones. There were dung stains behind the hind hoof marks. The distance from the wall to the front hooves indicates that the wall must have been low enough for the horses to get their heads over, as the length of the head and neck on even a small pony is longer then 45 cm. The distance between the front and hind hooves is also quite small and suggests horses not much bigger than 1220 mm based on the measurement of several modern ponies (C. Johnstone unpublished data).

There is some archaeological evidence in Britain that the covered exercise halls for training cavalryman and their mounts, mentioned in Vegetius, were built at Inchtuthil, Chester, Newstead (later 2nd century AD fort), Haltonchesters, Brecon and Netherby. All forts had parade grounds outside, which were used to train and exercise all the troops, including the cavalry. Many of these have been identified archaeologically and some extend over 4 ha. All have been found on areas of flat ground outside the forts themselves, but sometimes quite some distance away. That these parade grounds were for cavalry training as well as for infantry is attested to by the finds of altars and inscriptions to the *Campestres*, deities concerned with horses and men in training situations rather than war (Davies 1969).

Luff (1982) suggests that, judging by the very small quantities of bones of wild species in assemblages from most Roman period sites, hunting was not a major occupation of soldiers, farmers or settlers in general, within or outside the Empire. However, this only proves that the kills did not end up being deposited with domestic rubbish, perhaps indicating that they were not eaten.It does not rule out the possibility that they were caught but not eaten. Villa sites show higher proportions of wild animals, as might be expected from higher status rural sites. However, there is no zooarchaeological evidence regarding whether hunting took place from horseback (as seen in the mosaics mentioned above) or the horses were simply used as a means of transport for the hunters and their kills (as also described above).

Consumption of horsemeat

Based on the assumption that there was a taboo on the eating of horsemeat because it was thought to be unclean, there should be no evidence of butchery on the horse bones from Roman sites. In many instances across the Empire this is indeed the case, and even where there is some evidence of butchery it cannot be linked conclusively to the consumption of horsemeat by people. For instance, Luff (1982) suggests that traces of butchery on horse bones could indicate removal of meat to feed to dogs. The butchery could also be a means of reducing a carcass to more manageable pieces for easier disposal in pits or ditches, particularly where these bones are found separately from the deposition of other domestic refuse.

In Roman Gaul it was noted that large deposits of horse bones were occasionally found on the edge of towns (Arbogast *et al*. 2002). This was probably just a specific place to dump dead horses, as there is evidence they decomposed in the open air and dogs had access to the cadavers. A dump at one site had separated vertebral columns and showed a deficit of small elements, indicating that this was a secondary deposition of horse cadavers from another source. Other areas where contained deposits of artisan waste where the use of parts of the tibiae, radii and metapodials of horses for the manufacture of bone pins was evidenced.

Lauwerier's (1988) study in the Netherlands showed that more horse bones were found in rural settlements than in urban ones, except deposits from urban ditches and cemeteries outside the settlement area. It is suggested that this is indicative of rubbish disposal patterns (as discussed above) and not the occurrence of horses in general. In addition, whilst there are some cut marks, it is indicative of skinning or carcass division prior to disposal rather than butchery for meat.

In Britain, where horses appear not to have been consumed in quantity in the preceding Iron Age, there was obviously not a great change in diet required to conform to Roman practices. However, in other parts of the Empire a very different story emerges.

Arbogast *et al*. (2002) demonstrate that the butchery of horses for meat was very prevalent in Iron Age Gaul, particularly in the Paris Basin area, but that the quantity varies widely across Gaul. On some sites it appears that the occupants raised horses primarily for meat consumption, as many of the remains were killed at around four years old, when the animals have grown to a stage where the most meat is gained for the least input (like the cattle in a beef economy). On other sites the consumption of horsemeat appears to be on a more *ad hoc* basis. The remains of older individuals have been recovered, suggesting that the animals were only consumed after having been used for riding, traction or some other purpose. On one site with a large amount of butchered horse bones, the quantification suggests that whilst horse is fourth on the species list in terms of numbers of fragments, it is second behind cattle in terms of meat yield (Arbogast *et al*. 2002).

Many of the butchered horse bones in Iron Age Gaul (Arbogast *et al*. 2002) were found amongst other domestic refuse and not separately buried, compared with those from the Roman period mentioned above. Many different butchery techniques were present, some indicating secondary use of the carcass, including the heating of heads (evidenced by burn damage to incisors), possibly indicative of brain removal and the longitudinal splitting of heads and metapodials, for brain and marrow extraction. Evidence for the jointing of carcasses was present, including halving the carcass by splitting down the vertebral column.

In the Roman period, the taboo against eating horse seems to have held in most parts of Gaul despite the previous large-scale consumption (Arbogast *et al*. 2002). In urban settings and *vici*, very few horse bones were found amongst the domestic refus,e suggesting a lack of consumption. More horse bones are found in the deposits from rural settlements over most of Roman Gaul, but even there butchery traces are rare in comparison with the Iron Age material. The exception to this is in northern Gaul, where traces of butchery are still quite evident, suggesting that the isolation of this area from major trade routes and military zones meant that Roman practices were less widely adhered to. By the 4th and 5th centuries AD hippophagy (eating of horses) had become prevalent again in northern France, either as a result of Germanic population incursion or of a return to Iron Age practices.

Peters (1998) repeats that horse bones are rare in settlement layers on archaeological sites of the Roman period because they do not usually from part of the butchery or domestic waste. It is pointed out that this has a bonus for zooarchaeologists: because the horses' bones were not generally butchered, they are well preserved, with complete lengths, so many withers heights can be calculated. The contrast between the consumption of horsemeat on Roman sites within the Empire and the native settlements beyond, and the north-west German coast in particular, is striking. Examination of material from sites like Feddersen Wierde (Reichstein 1991) in the latter category, show that horsemeat was an important foodstuff there. The presence of large numbers of horse bones, including those from young animals, many displaying butchery marks, from these native Germanic sites indicates that horse rearing and horsemeat consumption were undertaken on a relatively large scale. So although the Roman view was that horsemeat was unclean, to other groups such as the Celts and Germans, it was a natural part of the diet.

In relation to this, there are sites within the Empire where horse butchery is in evidence. These are generally military sites and it is thought that this can be attributed to the presence of Germanic auxiliary soldiers. These auxiliary units were not subject to the control of the Roman administrative system, so it is possible that these soldiers could have followed their native customs in terms of diet. At Weißenburg and other forts on the *Limes,* horsemeat was certainly consumed and indeed could have formed a substantial part of the diet. However, a connection to troops of Celtic or Germanic origin cannot always be made clearly. In contrast, in urban situations chop and cut marks are seldom found on horse bones and their interpretation where present can be ambiguous regarding to whether the meat was for human or canine consumption, or whether other products were being utilised rather than the meat. In some cases the consumption of horsemeat may also have had something to do with status, because more horse bones with cut marks were found in the poorer districts of Augusta Raurica, for instance, than in the more affluent areas. Therefore it seems that, except under certain circumstances, the Roman taboo against eating horses was mainly adhered to in the Rhine-Danube area.

Horses in ceremonies and religion

The interpretation of deposits as having a 'ritual significance' is one of the stock phrases used by archaeologists for deposits that are peculiar in some way, i.e. they have no apparent explanation in terms of the perceived ordinary economic or domestic life of a site. Sometimes these deposits are clearly associated with structures other than domestic dwellings that have a role in the public life of settlement, such as a temple. Other deposits are associated with ordinary domestic structures but are unexpected in their position and/or content. Some of these deposits are termed 'votive' deposits as they are considered to be offerings to deities to invoke blessings.

Examples of Iron Age and Roman votive deposits that contain horse bones come from wells, bogs and other watery places. The Roman examples of these well deposits seem to exist in areas where sacrifices in watery places were also made in the Iron Age. For instance in Germany, the sacrifice of horses that are then placed in bogs is well attested in the Iron Age (such as at Oberdorla) and the tradition continues into the Roman period, both in bogs and in wells. Many of these votive deposits in watery contexts contain either whole skeletons of horses, or just the heads, or heads and feet together. In Britain, there are similar deposits to those in Germany; for instance, in Roman Chelmsford (Luff 1982) a well near the site of the *mansio* contained several horse skulls at the bottom. Some of these were adults but there were also juvenile individuals. There were no obvious signs of butchery on the bones, and whilst most of the remains were skulls, some post-cranial bones were also present. More skulls and other bones were also found in an adjacent ditch.

Similar traditions of votive offerings in watery places seem to have taken place in the Netherlands. During excavation of the *Fossa Corbuloni*s (Corbulo Canal, in Leiden-Roomburg), a deposit containing a bronze mask, unworn coins and a number of horse bones was recovered (Lauwerier and Robeerst 2001). The skull of an adult stallion of about 1360 mm withers height and the left hind leg of a much larger horse (about 1500 mm) were recovered all of which had been excessively heavily butchered. It is usually assumed that masks and helmets found in rivers were offerings from discharged soldiers giving thanks for protection during their military service. The offering of horse parts could have a similar significance if a cavalryman was giving thanks. The fact that the horse bones are heavily damaged might be paralleled in the deliberately smashed pottery and weapons rendered unfit for use found in other votive deposits.

Other instances of horse remains deposited in unusual places have been found in association with the construction of temples, other buildings and roads, and are termed ‘foundation deposits’. These are considered to be offerings to the deities for good luck to be bestowed on the building. Examples occur in Britain (Luff 1982) and also in the Netherlands (Lauwerier and Robeerst 2001). The villa site of Druten and the settlements of Wijster and Heeten (beyond the *Limes*) in the Netherlands all had horse burials situated very close to buildings, and the burial pits could be seen to have been dug at the same time as the buildings foundations. Similar burials were found at the Germanic settlements at Raalte-Heeten, Leidenschendam De Leeuwenbergh and Wijster, but these were more closely associated with the entrances of the enclosures and farmyards. These have been interpreted as site offerings, perhaps a Germanic imitation along the lines of *suovetaurilia* to invoke blessing of the settlement itself at its inception.

Although there are not a vast number of horse burials in the Roman period, particularly in comparison with the following Migration and early medieval periods, there is a scattering present in most parts of Empire. Luff (1982) suggests that there is a slight concentration in the mid-Danube basin (west Hungary and east Austria) perhaps as a result of the preceding Iron Age and earlier horse burial traditions. In some cases there can be problems establishing whether a horse burial is a ritual deposit or just the disposal of a dead animal. This is partly because it is difficult to establish a cause of death. Arbogast *et al.* (2002) argue that on sites where hippophagy was practised, such as those of northern Gaul, the burial of a whole animal is more likely to be a ritual deposit, unless the animal died of a disease that made it unfit for consumption. The position of the burial in relation to buildings, and the posture of the skeleton in the burial environment, may help to differentiate the two hypotheses put forward above. However, on sites where horsemeat was not consumed it is particularly difficult to establish the significance of a horse burial (Lauwerier and Robeerst 2001).

The use of horses as sacrificial victims is implied in diverse forms of rituals in Gaul, particularly in the later Iron Age (last four centuries BC) and the Roman period (Arbogast *et al.* 2002). The remains of horses are found in funerary contexts of cemeteries and as sacrifices in sanctuaries and temple areas. It makes sense that horses were used as sacrifices when they were a source of meat, just as other food animals were used to bring fertility to the herds and prosperity to the owners. This then gives an explanation of their use in ritual meals (Lauwerier and Robeerst 2001).

The association of horse burials with those of humans hints strongly at a ritual element. In Britain and Gaul humans and horses were buried in the same pits (often thought to be ex-grain silos) from the 5th century BC (Grant 1984; Arbogast *et al.* 2002). However, the remains are not always directly associated with each other as they often occur on different levels within the pits, and sometimes the heads and limbs have been, manipulated i.e. the remains are not always articulated. By the 3rd century BC in Gaul the association is clearer and the deposition of the remains was simultaneous. The funerary rites obviously varied considerably across Gaul in the Iron Age, as the inclusion of horses was rare. Even in the areas where chariot burials were prevalent, the horses were not always included.

Evidence for the sacrifice of horses is plentiful from ditches defining the limits of Iron Age sanctuary sites (Arbogast *et al.* 2002). On some sites the remains show that the cadavers were deposited whole in the ditches and then left in the open air to decay. In the ditches of some sanctuary sites it is evident that the horse remains were a secondary deposit, as only the heads and legs were found, so the bodies must have been decomposing elsewhere and only parts were re-deposited in the ditches. Alternatively, this could represent the primary butchery waste left from a ritual meal. Archaeology is not able to say whether these slightly different depositions of horse remains were part of similar ritual practices or very different ones.

In the Netherlands there are examples of horses in Roman cemeteries, but it is often impossible to confirm if these were contemporaneous burials or whether the cemetery happened to be located on a site where the burial of horses (for whatever reason) happened to have taken place. Beyond the *Limes*, at the site of Wijster there is no doubt that the cemetery contained the contemporaneous deliberate burial of horses as well as people. The horses were buried in a vertical standing or kneeling position within their graves and the graves were in neat rows. This formalized burial position suggests that these were animals buried with some degree of ritual. A similar cemetery was found at Drantum in NW Germany, so perhaps this was a regional Germanic custom (Lauwerier and Robeerst 2001).

In Roman Gaul, temples were often put on top of the Iron Age ones but most likely with some modifications regarding the rites and practices of the associated religion. The large numbers of whole skeletons found on some of these sites indicate the sacrifice of non-food animals, i.e. there was no ritual meal. However, it could be argued (Arbogast *et al.* 2002) that these are the remains of horses that died of natural causes and were disposed of in a new way, all together in a ritual setting, but this seems unlikely given the numbers of animals deposited at the same time. Other animals are sometimes included in these deposits, particularly canines.

The remains from various sites show different population statistics; at some sites all the remains appear to be from young animals, whilst at others they appear to be all male. The method of deposition also varies, at some sites all the bodies were buried the same way round in pits together, at others they were buried individually; on some sites the scatter of bones suggest that open air decomposition took place, and on others it is suggested that partly decomposed heads and legs were subsequently buried in other places. This practice of horse sacrifice *en masse* seems to be confined to northern Gaul during the Roman period.

The absence of horse bones at Roman temple sites in the Netherlands has led Lauwerier and Robeerst (2001) to conclude that 'the horse did not play any part in sacrifices or ritual meals in any of these temples or complexes'. Perhaps the most extraordinary evidence for ritual use of horses comes from a collection of bones found in a pit at Houten-Tiellandt in the Netherlands. Eighty-seven bones from a single five year old mare were found together but not in articulation and most of these bones showed chopping and cutting marks of various sorts. Initially it was considered that the flesh had been stripped off to feed to dogs, but this would not leave the kinds of butchery traces in evidence. Also there was no trace of dog gnawing on any of the bones. 'This extremely concentrated … consumption of such a large quantity of meat from an animal not normally eaten makes one suspect that these were the remains of a ritual meal' (Lauwerier and Robeerst 2001: 286). In addition, the large quantities of unbutchered horse bones from the rest of the site indicate that horses must have been an important component of the economy and may indicate horse breeding. Perhaps this ritual meal of horse was in honour of a horse-related deity.

As mentioned above (Section 1.3.1), cavalrymen worshipped a set of goddesses known as the *Campestres* whilst in a training situation (Davies 1969). Many altars dedicated to the *Campestres* have been found, located at cavalry exercise grounds rather than within forts. Examples have been found in Britain at Newstead, Castlehill, Cramond, Auchendavy and Benwell (Davies 1969).

1.5 Terminology

There is a group of terms in common usage in the zooarchaeological literature that are both ambiguous and quite often inappropriately used. In addition there is a further set of terms that it is appropriate to clarify at the outset of this research.

1.5.1 Breeds and demes

The most ambiguous word often used in association with domestic animals is 'breed', and it is often inappropriately applied to archaeological material. A breed of animal in the modern sense of the word is a group of animals that have shared, clearly defined characteristics in respect of size, conformation, action and in some cases also colour, resulting from human control of reproduction (Edwards 1993). Put another way 'a breed is a group of animals that has been selected by humans to possess a uniform appearance that is inheritable and distinguishes it from other groups of animals within the same species' (Clutton-Brock 1999: 40). In the case of horses and dogs, in particular, this is backed up by the existence of studbooks detailing all the ancestors of any individual registered as belonging to a particular breed. This means that the gene pool of any modern breed is very restricted as most studbooks have been in existence for no more than a couple of hundred years. Therefore any hybrids between breeds, or those animals without a pedigree, are not considered to belong to any breed. In view of these narrow definitions, it is entirely inappropriate to use the term breed to describe ancient groups of horses, the breeding of which is not known to have been controlled by humans in this way.

There are a number of alternative words that could be used to describe a group of animals within a species that have a similar appearance. These include 'type', 'race', 'variety', 'phenotype' and 'deme'. Amongst the equine community a 'type' of horse is one that has certain characteristics, like a breed, but does not have to have a pedigree. An example of this is the cob-type horse, a small (up to 15.1 hh), thickset horse with powerful shoulders and quarters and short strong limbs. It is useful for its weight-carrying ability rather than speed and is often used in harness as well as a riding animal (Edwards 1993). However, in biological circles 'type' is often used as an abbreviation for holotype, meaning the set of characteristics described from a single specimen used as the basis for classification of a genus or species (Lawrence 2000). Neither of these definitions is entirely what we are after and such variation in meaning is particularly confusing.

A 'race' is a 'group of individuals within a species, which forms a permanent and genetically distinguishable variety' (Lawrence 2000). A 'variety' is 'a taxonomic group below the species level'. Both of these can be, therefore, other words for a subspecies, which is not what a group of ancient horses constitutes. So both of these are also unsuitable for the purposes required here.

A 'phenotype' is defined in Henderson's dictionary of biological terms (Lawrence 2000) as '1) the visible or otherwise measurable physical and biochemical characteristics of an organism, resulting from the interaction of genotype and environment and 2) a group of individuals exhibiting the same phenotypic characters'. All modern breeds and types of horse are therefore phenotypes, as are all groups of ancient horses with shared appearances. However, this term has genetic connotations and the first part of the definition given above is the one most often used. Therefore, this is perhaps not the best term to use even if technically correct.

A 'deme' is 'an assemblage of individuals of a given taxon, usually qualified by a prefix e.g. ecodeme (a deme occupying a particular ecological habitat), gamodeme (a local population unit of a species within which breeding is completely random) or topodeme (a deme occupying a particular geographical area)' (Lawrence 2000). Whilst groups of ancient horses could in some ways be classed as both gamodemes and topodemes, the full definitions of these cannot be strictly applied. Therefore just the generic term can be used. The term 'deme' appears to be the most useful in terms of describing groups of ancient horses, as it has none of the connotations of a modern breed with its studbooks, or the confusion of meanings of the word type and is also not biased towards genetics or taxonomy. Therefore, throughout this work the word deme will be used to denote a group of equids with similarities in appearance.

1.5.2 Appearance and conformation

It has been mentioned above that horses and ponies have different conformation, with ponies having shorter legs in relation to the depth of the body. This is illustrated below in Figure 1.13. It can be seen that by rescaling the outline drawings of a typical pony breed (Exmoor), a typical light horse (Arab) and a typical heavy horse (Shire) to the same withers height that there are differences in proportion between the pony and the types of horse. In addition, a Lippizaner horse has been included as these are similar in proportion to the equestrian statues dating to the Roman period.

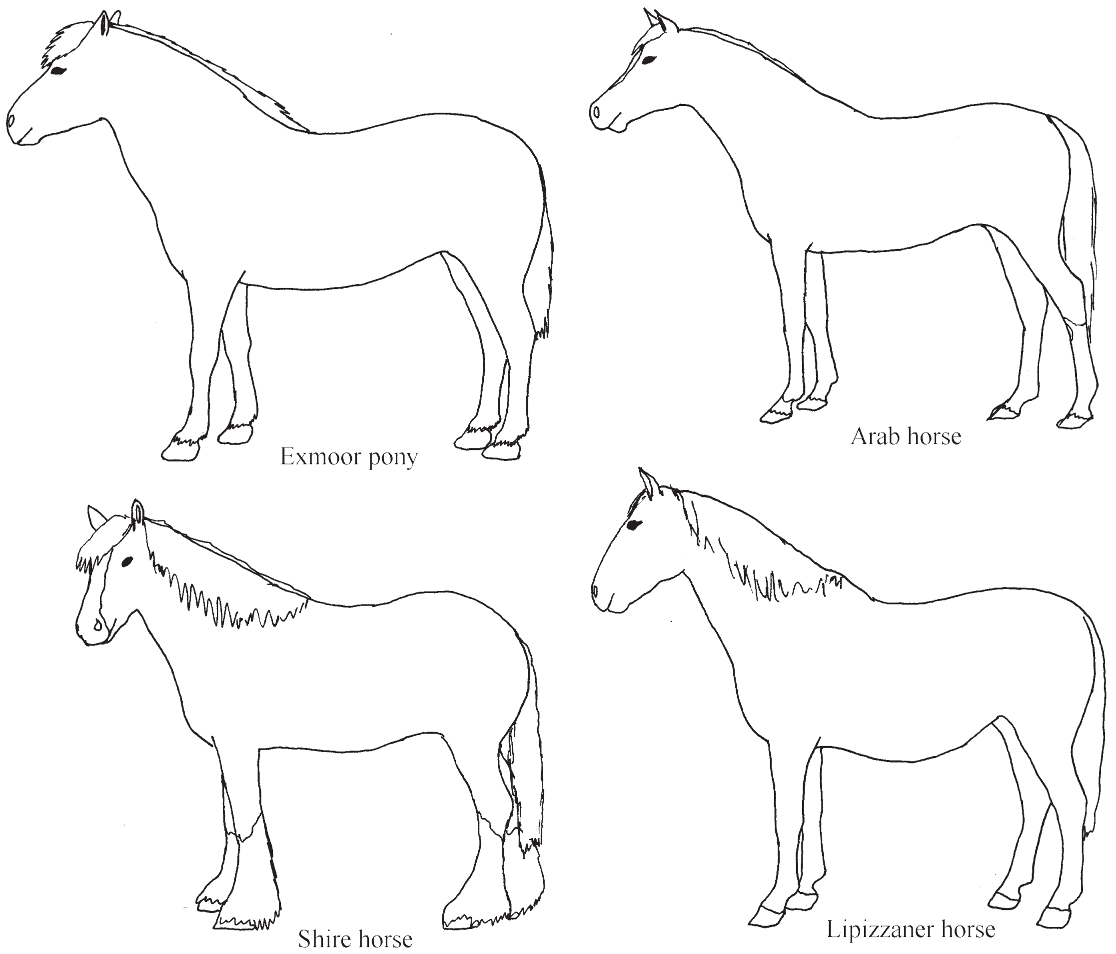

Figure 1.13 Line drawings of horse and pony breeds scaled to illustrate the differences between pony and horse conformation and between horse types (drawn by C. Johnstone).

1.5.3 Taxonomic nomenclature

The taxonomic nomenclature of domestic animals has been the subject of much debate (Clutton-Brock 1992, 1999; Uerpmann 1993), and a variety of forms is commonly used in zooarchaeological literature. In some cases a mixture of systems are used which further complicates the issue. There is also the problem that the wild and domestic forms of a species are not separate species in the genetic sense, as they produce fully fertile offspring when mated together. However, it is not practical to call the wild and domestic forms by the same name, as differentiation between the two is often crucial to zooarchaeological understanding. An example of the confusing situation is that both *Equus* f. domestic and *Equus caballus* have been used to denote domestic horses, whilst wild horses are usually termed *Equus przewalskii*. However, *Equus asinus* is often used to denote domestic as well as wild donkeys, although wild donkeys are sometimes given the additional suffix *somaliensis* or *africanus*.

There is not even no consistency within museums as to which system to use. This is particularly true with older specimens with labels that have not been updated since they were placed in the collection, often over a century ago. This can make secure identifications a little difficult when it is unclear whether two specimens are actually the same species or not.

Bohlken (1961 quoted in Clutton-Brock 1999) proposed one system that was accepted, mostly in Germany. His solution 'was to call the domestic form by the first available name for the wild species, followed by the linking word 'forma' (f.) and then by the earliest name, according to the rule of priority, for the domestic animal'. Using this system a domestic horse would be called *Equus ferus* f. *caballus*. Zeuner (1963 quoted in Gautier 1993) suggests a similar system to that of Bohlken, but adds 'f.d.' (forma domestica) between the species and subspecies names. Dennler de la Tour (1968 quoted in Gautier 1993) proposes that instead of 'forma' or '*forma domestica*' the word *'familiaris'* should be used to denote the domestic form. Under this system the horse would become *Equus ferus 'familiaris'*. This system allows for the naming of feral animals by using *'exfamiliaris'* which would mean that the mustangs of North America could be named *Equus ferus 'exfamiliaris' mustang*.

As can be seen all these are rather clumsy and long-winded systems, which have never really been accepted into mainstream zooarchaeological literature. They also suppose that all domestic animals are descended from a single known wild species, which is also a very debatable issue, particularly in reference to horses. To get around this problem Uerpmann (1993) proposed an entirely new system of nomenclature for domestic animals, which is based on a single word name written in italic capitals. This single word is mostly the Linnaean species name, hence a horse would just be *CABALLUS*. He goes on to suggest that breeds and types could be added to this name in the following form, *CABALLUS* 'Exmoor' for the Exmoor pony and *CABALLUS* t. cob (t = typus) for a cob-type horse. This system has some advantages as it is separate from the taxonomic system and its difficulties in relation to domestic animals, but is perhaps too radical to become commonly used, i.e. it has not come into general use and will not be used here.

Clutton-Brock (1992, 1999) suggests that the oldest name should be used for the domestic form and the next oldest name for the wild species. This is also the recommendation of the International Council for Zoological Nomenclature (Gentry *et al.* 1996). Following this system *Equus caballus* is used for the domestic horse and *Equus asinus* for the domestic donkey. The wild forms become *Equus ferus przewalskii* (wild horse) and *Equus africanus somaliensis* or *Equus africanus africanus* for wild donkeys (depending on the subspecies). As these seem to be the most commonly used (and by implication the most widely understood) Latin names for equids, as well as the officially recognised ones, they will be used throughout this work.

The naming of hybrids is perhaps even more debatable and often incorrect. The hybrids that concern us here are the mule and the hinny, both of which are crosses between horses and donkeys. The mule is the cross between a male donkey (jackass) and a female horse (mare) and its Latin name is *Equus asinus* x *Equus caballus:* the first part always being the sire. The hinny is a cross between a male horse (stallion) and a female donkey (jenny) and its Latin name is *Equus caballus* x *Equus asinus*.

1.5.4 Use of the term species

In relation to the taxonomic nomenclature of the equid species and their hybrids, it is awkward to have to refer to both species and hybrids when discussing the horses, donkeys and mules together. Therefore, throughout this thesis the term species will be used to denote both the true species (horses and donkeys) and the hybrid mules. Although it is acknowledged that this is not strictly zoologically accurate, the simplification will allow for less verbiage in the remainder of the text.

1.5.5 The measurement unit hands

Measurement of the height of horses, particularly in Britain, has traditionally been carried out in the unit of hands (hh), which according to Edwards (1993) has medieval origins. The measurement is taken from the ground to the withers, the slight upward protuberance of the vertebral spines at the base of the neck just in front of the saddle. One hand is equivalent to 4 inches, so therefore a horse that is said to be 15.1 hh is 15 multiples of four inches plus one inch: 61 inches or 1549.4 mm. The abbreviation 'hh' stands for hands high.

It needs to be stressed here that a measurement quoted as 14.2 hh means 14 hands and 2 inches high, and **not** 14.2 with a decimal point. Occasionally, workers have misunderstood the hands measurement, i.e. withers heights are quoted as 12.8 hands in Luff (1982) when this should be 12.3 hh as there are only 4 inches to each hand (see Section 1.5 and Chapter 3), so if a publication quotes a value of 14.5 hh, for example, it is wrong and perhaps the metric equivalent should looked at instead if this is given. The metric conversion of inches to millimetres gives a value of 25.4 mm to 1 inch, so one hand (4 inches) is 101.6 mm. These are the figures that will be used to calculate the withers height in Hands from the calculations based in mm.

Hands are the measurement cited widely in zooarchaeological literature for horse withers height (in addition to the metric values), because they are widely understood and used by those who deal with live horses and can therefore be compared with extant breeds, whose sizes are mostly quoted in hands. In this thesis, metric values for withers heights will mostly be quoted, as calculations will be carried out using bone measurements in millimetres. However, where appropriate hand measurements will also be given for clarity and comparative purposes.

1.5.6 Use of the terms Iron Age, Roman and External

In a similar way to the use of species outlined above to cover both true species and hybrids for simplification, the terms Iron Age, Roman and External will be used as outlined here. There is much debate about the use of these and other similar terms in the literature (e.g. Wells 2001) but it is felt that as long as the meaning of the terms, as they will be applied in a piece of work, are made clear at the beginning then, although perhaps not strictly correctly used, they will at least be understood.

In this research the term Iron Age will be used to describe any material dating to the last few centuries preceding the conquest of an area by the Romans. This will include any contemporaneous material from areas that were never conquered.

The term Roman will be used to describe any material dating to the period between the conquest of an area by the Romans and the official withdrawal of military and administrative support by Rome.

The term External will be used to describe any material dated to the same period of time as that of the Roman material but that comes from areas that were not conquered by the Romans, i.e. were external to the Roman Empire. It is acknowledged that this was still technically the Iron Age in these areas, but to avoid unnecessary confusion between two uses of the term Iron Age it is felt that the term External is more appropriate for this material.

1.6 How the subject is to be addressed

There are two main sections to the research project: the first deals with the issue of species and hybrid identification amongst the equid remains, and the second with the issue of appearance in terms of size and shape of these equids. To address the first issue a number of approaches were tried. Initially an assessment of the previously published methods of separation was carried out. To enable objective evaluation of the methods currently available, it was necessary to collect data from modern reference specimens of known species or hybrid in museum and other collections (see Chapter 5). The methods tested included the use of morphological characteristics (e.g. Armitage and Chapman 1979; Davis 1980) and biometrical techniques. The latter included the use of log-ratios (Eisenmann 1986; Eisenmann and Beckouche 1986) and multivariate analysis (Dive and Eisenmann 199; S. J. M. Davis, unpublished data) (see Chapter 4).

The next stage wall be to apply whichever methods of species separation was most appropriate to the archaeological data. The data for this primarily were collected from published information on equid bones recovered from archaeological sites across the Empire (see Chapter 5). The chosen methods were used to verify or contradict the few existing identifications of donkeys and mules in the zooarchaeological literature (Kunst 2000; von den Driesch and Cartajena 2001). Then the methods were applied to the main body of data recorded as 'horse' to check that mules and donkeys had not been included in this group. This forms the first part of the results in Chapter Six (Section 6.1).

The second area of research was carried out using the archaeological biometrical data mentioned above to investigate the size and shape of the Roman equids. Analyses included the use of withers height estimation, shape index calculation and log-ratio analysis (all methods outlined in Chapter 3). Although it was suspected that the smaller numbers of identified mule and donkey bones would prevent much statistically valid further work from being undertaken, the same analyses were applied to all three groups in order to form the basis for inter-species comparisons. In addition, intra-species comparisons were made between the equids of different periods, geographic areas and site types.

The results (Chapter 6) are split by analytical method (Sections 6.2 - 6.4) and then an overall summary (Section 6.5) brings them together. The results are then discussed (Chapter 7) in relation to the research aims and questions put forward above.

Chapter Two – Bone and skeletal biology

2.1 Introduction

The role of this chapter is to provide an understanding of the basic biology of the material to be used in this study, namely bone. The reasoning behind providing this is that there are a number of issues relating to the growth of bones and the skeleton that could affect the results of the study, or at least should be borne in mind when interpreting the results. The following sections look at bone as a biological substance, how individual bones and the whole skeleton grow under ideal conditions, and lastly factors that can affect that growth pattern. This section will include such issues as age, sex (including castration), nutrition, hormones and disease. These are necessarily dealt with relatively briefly, as whilst there is a vast veterinary literature dealing with these issues in minute biological detail, most of that detail is inappropriate to this study. Most of the information on the factors that affect growth in equids is concentrated on the horse, partly because the horse is a commercial animal and partly because there are far fewer donkeys and mules in existence (particularly in English-speaking countries).

2.2 What is bone?

Bone is the hard tissue that forms the internal skeletons of all members of the phylum Chordata and first appeared in the fossil record around 500 million years ago. Its structural roles include supporting the body against gravity, acting as a rigid lever system for muscular action, and providing protection for vital internal organs. In addition, bone is a metabolic tissue, serving as a repository for calcium and inducing marrow formation (Bouvier 1989). Cortical bone provides the mechanical and protective functions, whilst cancellous bone provides the metabolic function (Marks and Hermey 1996).

Bone is a living tissue that contains two main components, one organic and one inorganic. The main inorganic component of vertebrate bone is calcium phosphate in the form of hydroxyapatite (85%), $Ca_{10}(PO_4)_6(OH)_2$, together with calcium carbonate, $CaCO_3$ (10%). The organic component is composed of 95% collagen and 5% proteoglycans such as chondroitin-4-sulphate (Marks and Hermey 1996; Saladin 1998). Collagen is a fibrous protein consisting of aggregations of tropocollagen macro-molecules. Each of these comprises three polypeptide chains with a left-handed helical structure. These are twisted together to form a right-handed spiral. The complete amino acid sequence of this protein is extremely complex and somewhat variable. The three strands are hydrogen-bonded to each other internally and also to neighbouring fibrils

(Halstead 1974). Within the structure of bone, the inorganic compounds confer rigidity and hardness to the structure, whilst the organic material confers toughness, resilience and elasticity (Reitz and Wing 2000: 39). The structure is analogous to reinforced concrete. Like concrete, the minerals resist compression, whilst, like the steel reinforcement bars, the collagen resists tension (Saladin 1998).

There are four types of cell associated with bones, outlined below. (from Bouvier 1989, Halstead 1974, Marks & Hermey 1996, Saladin 1998)

1) Osteoblasts differentiate from osteogenic cells, which come from embryonic mesenchyme. They are typically cuboids, with a single nucleus at the opposite end to the extensive endoplasmic reticulum and a large Golgi apparatus. These structures are involved in protein production and secretion and they regulate mineralisation. Hence osteoblasts are the cells primarily responsible for bone production by collagen production and calcification.

2) Osteocytes are osteoblasts that have become trapped in the bone matrix as the bone grew. Their internal structure has changed and lost most of the cellular organelles and the cells become flattened with 'tentacles' going from them to neighbouring osteocytes through canaliculae in the bone structure. These tentacles provide a network through which substances can pass to repair and maintain the bone structure, which is the primary function of osteocytes.

3) Osteoclasts arise from the fusion of many monocytes (a type of white blood cell) and are, consequently, large cells with multiple nuclei. They also have a large Golgi apparatus and a characteristic ruffled membranous border. The primary function of osteoclasts is the resorption of bone. The ruffled border attaches to an area of bone to be resorbed, the Golgi apparatus produces lysosomes for breaking down bone structure, and particles of detached bone are taken inside the cell in vacuoles to be broken down further.

4) Bone-lining cells are flat, elongated, inactive cells with very few organelles. They cover bone surfaces that are not undergoing formation or resorption and may be precursors for osteoblasts.

There are two types of bones within the skeleton of a mammal classified according to the way in which they grow (Reitz and Wing 2000). Endochondral (cartilage replacement) bones are those that form indirectly by replacing a cartilage precursor and include most of the limb bones of mammals. Intramembranous (dermal) bones are those that form directly in the connective tissue of the epidermis and include most cranial elements of mammals. Both require a solid base and a well-developed vascular supply (Marks and Hermey 1996).

In addition there are many types of bone structure that can be present within a single bone. Those that are found in mammalian bone can be classified as immature (woven) bone, primary vascular (lamellar) bone, secondary lamellar (Haversian) bone, and plexiform (laminar) bone (Currey 1998). It should be noted that this is only one of several such classifications, one that suffices for this research.

Immature or woven bone has randomly orientated fine (about 0.1 μm diameter) collagen fibres. As well as being characteristic of young bone it is also found during the initial repair phases after injury to bone. Primary lamellar bone has precisely arranged collagen fibres and is commonly found in the long bones of adult mammals. The collagen and its associated mineral are arranged in sheets (lamellae) that encircle the longitudinal axis of the bone. The collagen fibres are much thicker than in woven bone (2-3 μm diameter) and are arranged in bundles, orientated the same way within small domains, but not throughout the lamella (Currey 1998).

Plexiform or laminar bone is found particularly in large mammals, whose bones have to grow rapidly in diameter (i.e. faster than lamellar bone can be laid down). Essentially, a scaffolding of woven bone is laid down, to be filled in later with lamellar bone. This creates alternating layers of parallel fibred, heavily mineralised woven bone and lamellar bone wrapped around the bone (Figure 2.1a). Sometimes these layers form around a blood vessel and look superficially like a Haversian system. However, these are termed primary osteones because they form as the bone grows, rather than replacing existing bone as Haversian systems do.

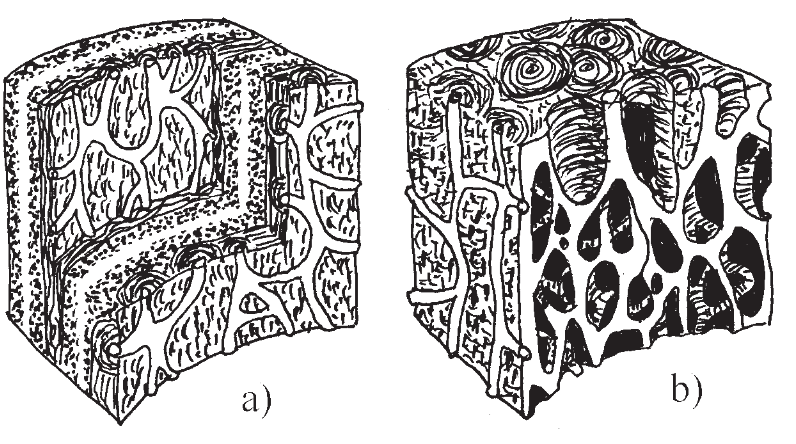

Figure 2.1. The structure of plexiform or laminar (a) and Secondary lamellar or Haversian bone (b) (C. Johnstone after Halstead 1974)

Secondary lamellar or Haversian bone is more complex than primary lamellar bone and contains Haversian systems (secondary osteons) (Figure 2.1b). Haversian systems, or osteons, are formed by osteoclasts (bone destroying cells) 'cutting' a cylindrical canal through the existing lamellae down the axis of the bone. These are then filled in by osteoblasts (bone manufacturing cells) with concentric lamellae around a central canal that can contain blood vessels and/or nerves (Currey 1998) (Figure 2.2). Haversian canal formation is a very variable process. In humans most long bones develop numerous Haversian canals, whereas in bovid long bones the laminar bone remains intact in most places with few Haversian systems, and in small mammals the bone most often stays as circumferential lamellar bone (Currey 1998). Haversian bone is less efficient than laminar bone because the vascular supply is not so good. It is also mechanically weaker for the same reasons. However, laminar bone is not so adaptable and it seems that Haversian bone is the usual form encountered after the initial period of growth (Halstead 1974).

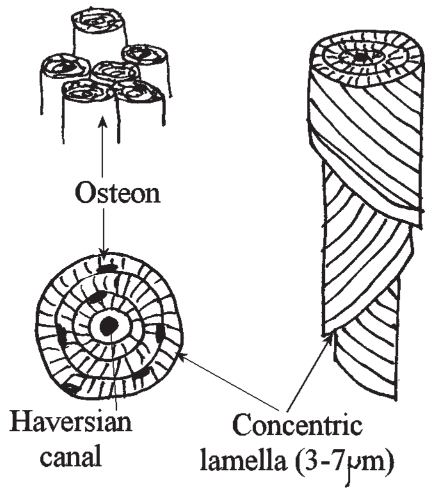

Figure 2.2. Microscopic structure of an osteon (C. Johnstone after Halstead 1974)

The mature bone structure of many mammalian long bones contains a combination of cancellous trabecular bone and compact bone. Cancellous bone has an open, porous or spongy appearance, made up of bony struts or trabeculae that give the structure strength but make it lighter than compact bone. Compact bone is made up of Haversian bone, and the periosteal membrane that surrounds the bone secretes layers of cortical bone on both the inner and outer surfaces of the cortex. Compact bone is most often found in the shafts of long bones, whereas cancellous bone is usually located at the ends of long bones (Figure 2.3).

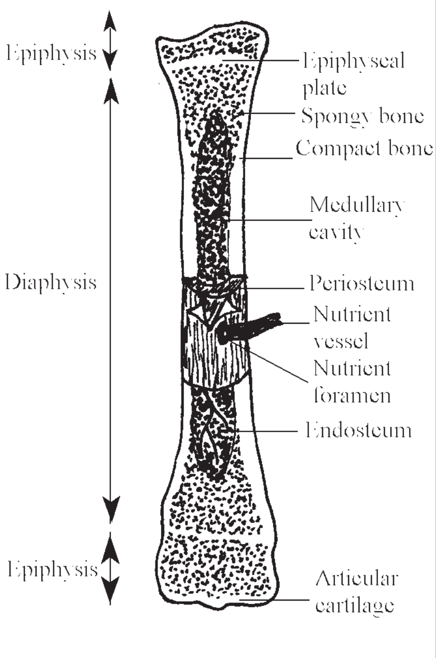

Figure 2.3. The structure of a typical long bone (C. Johnstone after Saladin 1998).

All bones can adapt and change according to circumstances. In an adult human, each year about 18% of the calcium in the bones is exchanged with that in the bloodstream, and at any one time about 5% of the skeleton is undergoing remodelling (Saladin 1998: 239). Many of the bony processes on the human skeleton are formed when a child begins to walk but can also adapt to changes in loading requirements through life. For instance, continued and extensive use of one muscle group will cause the bones to which these muscles are attached to become more robust to withstand the stress placed upon them. Examples of this include unequal humerus size in tennis players and heavily developed greater trochanter of the femur in weightlifters.

Bones can also repair themselves when injured. When a fracture happens the blood vessels are also broken and these bleed at the fracture site, forming a clot called a haematoma (Figure 2.4a). Blood vessels then grow into this soft (granulation) tissue, bringing macrophages to clean up the tissue debris, as well as osteoclasts, osteoblasts and fibroblasts. The fibroblasts then deposit collagen and chondroblasts produce patches of cartilage (Figure 2.4b). This resulting soft callus is subsequently mineralised by the osteoblasts and becomes a hard callus forming a collar around the periosteal and endosteal surfaces of the fracture, acting as splint. The callus persists for 3-4 months as the osteoclasts dissolve the necrotic bone and osteoblasts bridge the gap with spongy bone (Figure 2.4c). This is then remodelled into compact bone and eventually the callus is resorbed (Figure2.4d) (Halstead 1974). Even a severe fracture can be impossible to detect after a period of several months if the bones are realigned correctly at the time the fracture occurs.

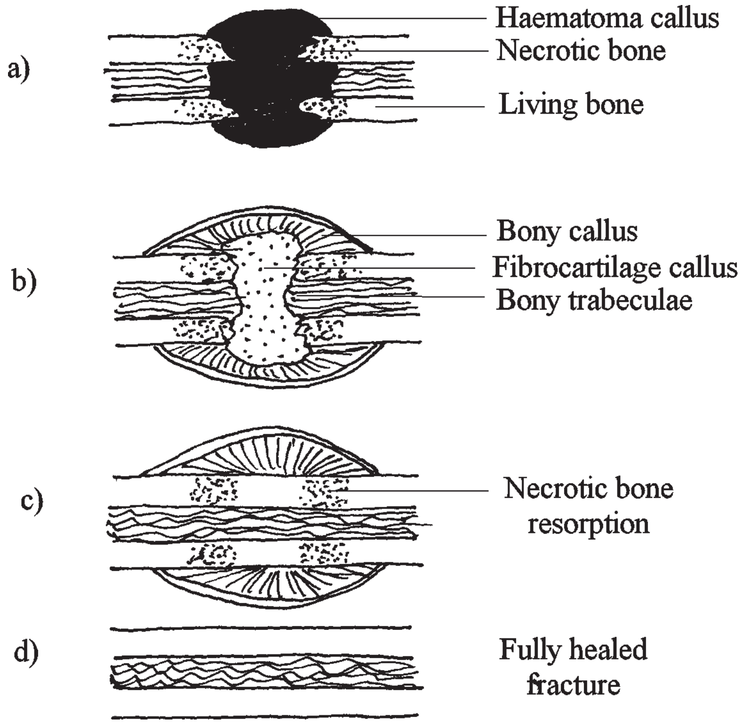

Figure 2.4. Stages in the healing of a bone fracture (C. Johnstone after Halstead 1974).

However, if the bones did not correctly align this would be detectable in archaeological bones as a deviation from the appearance of a normal bone. This deviation can take a variety of forms depending on where the fracture took place. In the context of this study, most types of non-aligned fracture are readily recognisable and measurements would not be taken on such a bone, however where a comminuted fracture takes place it is possible that the length of the bone ends up shorter, without appearing out of alignment. In this instance the resulting bone would not be recognised as a fracture case and could be measured, giving outlying values within a distribution. This type of fracture and consequent healing is, however, quite rare, particularly in equid bones, and therefore not all that likely to be found archaeologically.

Skeletal adaptations to a particular mode of locomotion should be mentioned here. In the case of horses the particular mode of locomotion of concern is running. This is the result of natural selection pressure on a prey species: the need to escape predators. Skeletal adaptations to running can be seen clearly in the limbs of horses (Figure 2.5). They have long straight elements, with the radius and ulna fused together (the latter also being reduced). The fibula is so reduced as to be almost absent. The metapodia (and phalanges) are reduced to a single functional element and are very elongated; and finally contact with the ground is only made with the tip of the third (or terminal) phalanx. Locomotion on the toes only is known as unguligrade. These adaptations give a greater rigidity to the joints of the long limbs and enable the animal to take longer strides and hence run faster (Figure 2.6).

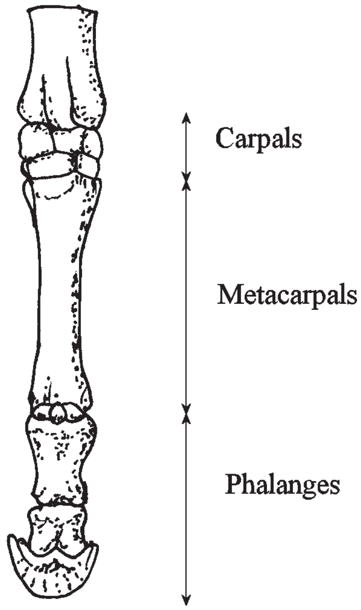

Figure 2.5. The lower forelimb of a horse showing the elongation of the metacarpals and the reduction to a single phalanx, giving a greater length of stride and hence speed.

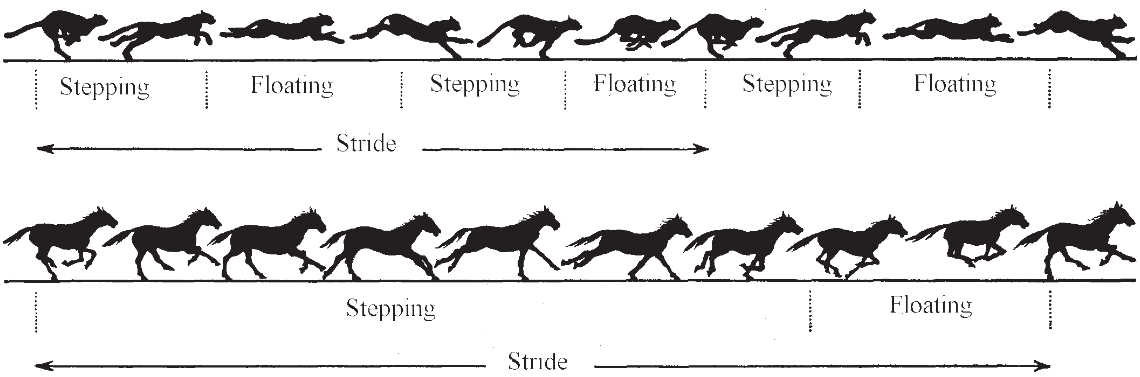

Figure 2.6. Illustration of the length of stride of a horse compared with that of a cheetah. On this evidence a horse should be the faster, but a more flexible spine generates the cheetah's extra speed (after Halstead 1974).

The swivelling action of the scapula also increases speed (Halstead 1974). Ungulates have suspensory ligaments that run from the posterior of the metapodials to the anterior of the terminal phalanx. When the toe is on the ground these are stretched, so that when the toe is lifted the ligament contracts, to give added impetus to the upward movement of the limb (Halstead 1974).

As the length of the leg is important in escaping prey, this is the reason that foals are born with very well developed limbs. At birth their legs are 73% of the length when adult, allowing them to run almost as fast as the adults from the moment they can stand. Moreover, because of the length of gestation (11 months) the foal is also quite mature at birth, allowing it to stand almost immediately and run within an hour of birth. These are very important adaptations for a prey species.

2.3 Bone growth under ideal conditions

The growth of the two types of bone, endochondral and intramembranous, is completely different. Intramembranous bones grow from a centre of ossification but do not have a cartilage precursor. 'Intramembranous ossification occurs during embryonic development by direct transformation of mesenchymal cells into osteoblasts' (Marks and Hermey 1996: 9). The mesenchyme forms a highly vascular sheet in the location of the future bone. Its cells enlarge and differentiate into osteoblasts, whilst some of the mesenchyme condenses into soft trabeculae. The osteoblasts then transform this into soft bone tissue, the trabeculae of which are subsequently thickened and mineralised. At the surfaces the trabeculae undergo further calcification to close up the gaps and convert to compact bone (Saladin 1998).

The bone grows outwards around the edges and growth ceases when it comes into contact with neighbouring bones. The joins between dermal bones are known as sutures and these continue to remodel and fuse after growth has ceased. This type of bone growth is found in the mammalian cranial vault, some facial bones and parts of the mandible and clavicle. For this reason it is not so important to study its growth in relation to an investigation regarding size and shape in archaeological equine material because the skull is rarely found intact enough for good analysis to take place, and there are no clavicles.

Endochondral growth, on the other hand, is of vital importance to this research as this is the type that occurs in bones with joints and that bear weight. 'Endochondral ossification is a method by which the unique properties of cartilage and bone are exploited to provide a mechanism for formation and growth of the skeleton' (Marks and Hermey 1996: 10). In foetal and neonatal individuals the bones are formed when 'condensed embryonic mesenchyme transforms into cartilage which reflects in both position and form the eventual bone to be found at the site' (Marks and Hermey 1996: 10). Ossification takes place as the individual grows.

Each bone has at least one centre of ossification within each cartilaginous precursor. For long bones the primary centre of ossification is located in the centre of the shaft or diaphysis (Figure 2.8a). Ossification of the diaphysis takes place here and occurs by the proliferation of chondrocyte columns, their hypertrophy and mineralisation (Figure 2.7). The persistence of the mineralised cartilage after the destruction of the cells acts as a scaffold for bone formation. Lengthwise growth progresses from the centre towards the ends of the bones, with resorption of the internal trabeculae to form the marrow cavity (Marks and Hermey 1996). Bone growth in diameter is achieved by the formation of bone on the outside of the diaphysis (periosteum) and resorption on the internal (endosteal) surface.

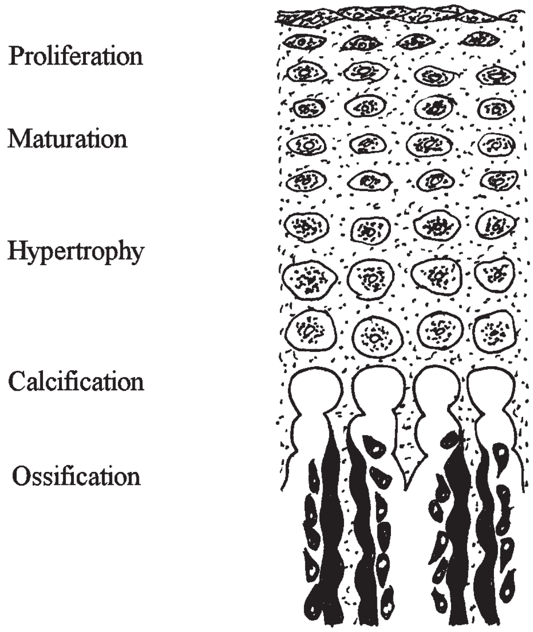

Figure 2.7. A schematic diagram of the process of cartilage mineralisation during bone formation (C. Johnstone after Halstead 1974).

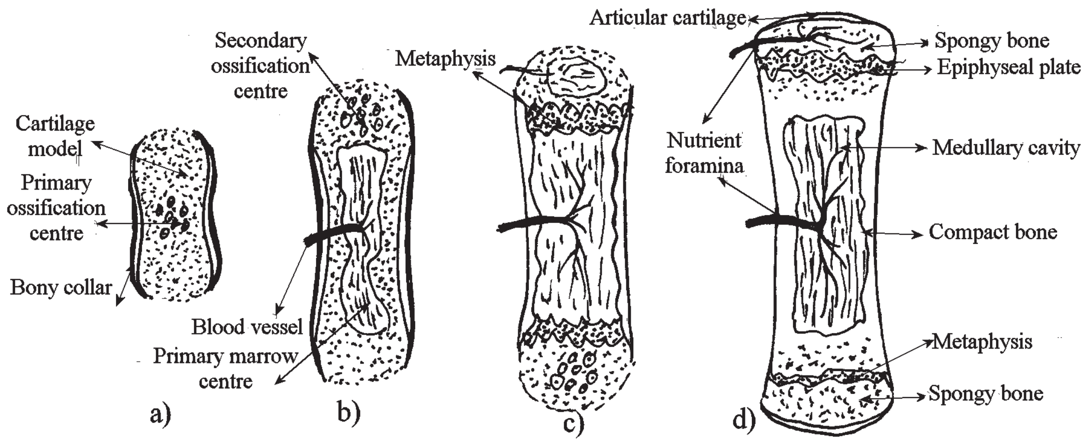

Figure 2.8. The sequence of ossification and bone growth in a mammalian long bone (C. Johnstone after Saladin 1998).

Secondary centres of ossification form at the ends and are called the epiphyses (Figure 2.8b). Growth takes place between the diaphysis and epiphyses in the cartilage disk that separates them, called the epiphyseal plate or metaphysis (Figure 2.8c) (McIlwraith 1996). Where the diaphysis meets the epiphysis it is flared outwards and is substantially wider than the centre of the shaft. This is called the periosteal collar and surrounds part of the growth plate cartilage. As the shaft lengthens a new periosteal collar is formed and the old one is remodelled to narrow it to the width of the shaft. This is achieved by resorption at the periosteal surface and formation on the endosteal surface (Marks and Hermey 1996) (Figure 2.9).

When the bone has reached adult size the cartilage of the epiphyseal plate stops growing and is replaced by bone, thus fusing the epiphyses and diaphysis (Figure 2.8d) (Halstead 1974; McIlwraith 1996). In some elements there are several epiphyses at one end of the bone, which fuse together prior to fusing to the shaft. In other elements (carpals and tarsals) growth occurs from a single centre of ossification with no epiphyses. The epiphyseal line is eventually completely remodelled away.

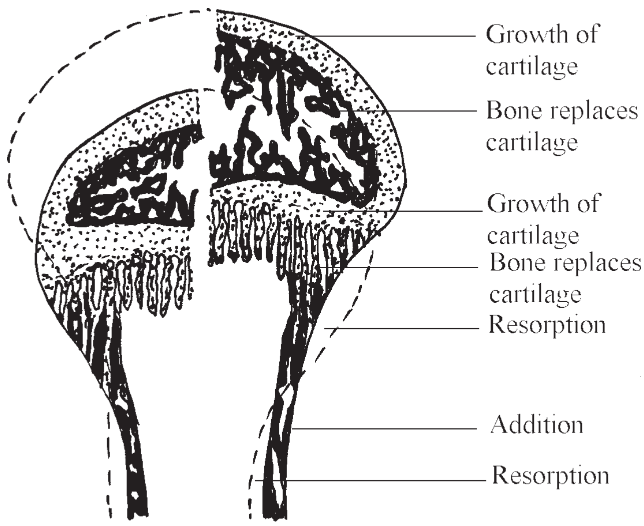

Figure 2.9. The process of lengthening bones during growth (C. Johnstone after Halstead 1974).

Regarding the growth of the whole skeleton rather than individual bones, there are two parts to the growth: one in pre- and the other in post-natal life. However, these should be seen as one continuous, rather than two separate, processes. 'During growth all organisms, except the simplest, not only increase in size but also undergo changes in form due to differential growth rate of their constituent parts' (Pálsson 1955: 430). Also 'in mammals having determinate growth, the external form changes continually during the period of growth, and as soon as the form becomes constant growth ceases' (Pálsson 1955). There is therefore a prescribed sequence to the growth of an animal that is well understood and will be described here.

There are two areas to discuss, firstly where bone growth fits into the overall growth pattern of a young animal, and, secondly, how skeletal growth proceeds. From conception to maturity there are a number of growth 'waves' that pass through the body, each causing a peak in growth rate of different parts and tissues of the body in turn. In terms of areas of the body, the head grows first, followed by the neck, thorax and loin. In terms of tissue development the brain and nervous tissue develop first followed by the bones, muscles and finally the fat reserves (Pálsson 1955). The appearance of a newborn foal reflects the fact the foetal growth has concentrated on the development of the head, central nervous system and bones. As post-natal growth occurs there is a shift from bone growth in the limbs towards the growth of muscles, particularly in the thorax and loin areas.

Also during foetal life the head seems disproportionately large in comparison with the rest of the body. In late foetal life the metapodials also grow considerably, giving the 'leggy' appearance of newborn animals. As post-natal growth proceeds, the wave of skeletal growth passes from the cranial vault down to the face and along the spine from head to tail, as well as up and down the legs from the metapodials (Figure 2.10). This is also reflected in the timings of epiphyseal closure, as given in Table 2.1. Because growth proceeds from the head backwards, the forequarters are better developed at birth than the hindquarters. As the foal grows a 'see-saw' effect can be observed between the height of the fore and hindquarters, as first the bones of the hind limb catch up with the growth of those in the forelimb and then the same thing happens with the muscle development.

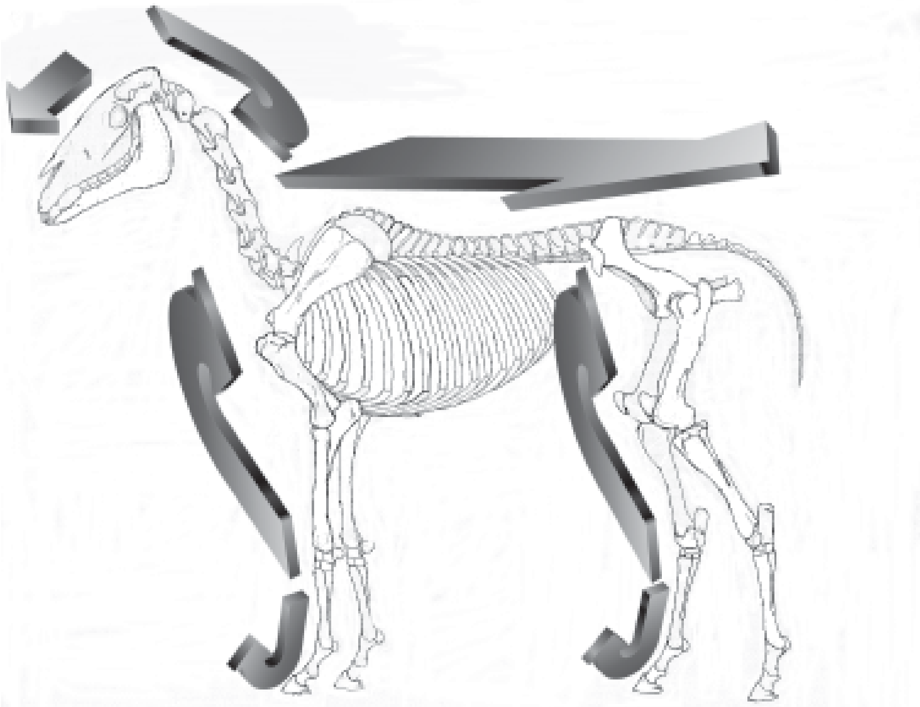

Figure 2.10. Horse skeleton with arrows showing the direction of the 'waves' of growth intensity as the skeleton matures (drawn by C. Johnstone).

In addition, the growth in length of the bones attains its maximum rate before the growth in thickness, meaning that once the maximum length is achieved the bones will still continue growing in diameter for a while after epiphyses have closed. This is also true of the body as a whole, with the height increasing least and width the most, with length of body and depth of chest intermediate in relation to the proportions at birth. Therefore at maturity the leg length is 1.38 x that at birth, whilst the width of the hips is 2.68 x that at birth, with depth of chest intermediate at 2.13 x the measurement at birth (Pálsson 1955).

2.4 Factors affecting bone growth

2.4.1 Age

Age and size are very closely linked in all species. However, in animals that have a determinate growth pattern (i.e. they reach adult size and stop growing) this only applies to immature individuals. There are two main age-related developments in animals with determinate growth patterns: remodelling to assume adult shape and size, and a reduction in bone porosity. It is important to highlight here that there are two types of 'age' when studying growth: physiological age and chronological age. Chronological age is the amount of time for which the animal has been alive. This is mostly measured in days/weeks/months/years since birth, although foetal life is sometimes included when studying the complete growth pattern of an animal. Physiological age is the stage of development that the individual has reached. This can vary considerably in relation to the chronological age of the individual, from conception to cessation of growth.

Foals are born at a much greater physiological age than many other animals as a result of their long gestation period, with their birth weight being around 10% of their adult weight (Pálsson 1955). Also the limbs of horses are so well developed at birth that very little length growth occurs below the hocks after birth, hence the phalanges (and to a lesser extent the metapodials) fuse early in life. At birth the leg length (ground to elbow) in a foal is 73% of the adult length and similarly the withers height is 60% of that achieved at maturity, indicating that the chest depth increases more than the leg length after birth (Pálsson 1955). Correspondingly the width of the chest and hindquarters develop to an even greater extent during postnatal growth. The reasons for this become clear when the sequence of growth is studied.

Studies have been carried out regarding whether the age of weaning affects bone growth and density in foals. Weaning is one of the most stressful events in a foal's life and often leads to a decrease in the growth rate. In particular, the loss of the calcium and protein from the mare's milk can reduce the rate of bone formation after weaning. By studying the bodyweight, withers height, metapodial circumference and bone density of foals weaned at 4.5 and 6 months, Warren *et al.* (1997) were able to establish that whilst weaning affected the weight gain of the foals initially, there was no difference between the early and late weaned groups after a few months. Growth in height and bone density of both groups remained unaffected by weaning. However, whilst the growth in metapodial circumference of both groups was affected by weaning, the early- weaned group was more severely affected, even at a few months after weaning (Warren *et al*. 1997). As the study did not follow the horses to maturity it is unclear whether this difference was still evident at maturity and would therefore affect the measurements of archaeological material.

As discussed above, epiphyseal closure is what limits the longitudinal length of the bones. The sequence in which the epiphyses fuse remains constant even when the exact chronological age at which they do so can be affected by nutrition, health, sex and individual variation. Table 2.1 gives the sequence and approximate timings of epiphyseal fusion based on the data of Silver (1969). These data are based on observations of modern horses (breed unspecified), and whilst Silver (1969) comments that horses have retained a slower skeletal development than other domestic animals, the timing of these closures may be less accurate in more 'primitive' breeds. In addition, these data are based on animals on a high plane of nutrition allowing optimum growth; a lower plane of nutrition can seriously delay epiphyseal fusion. Therefore, Table 2.1 should be used as a guide to the age of an individual, rather than providing absolute values.

Table 2.1. Sequence of epiphyseal fusion in horses and approximate ages at which this occurs (taken from Silver 1969)

Bone	**Epiphysis**	**Approximate age**
Metacarpal/metatarsal	Proximal	Pre-natal
1st phalanx	Distal	Pre-natal
2nd phalanx	Distal	Pre-natal
2nd Phalanx	Proximal	9-12 months
Scapula	Glenoid tuberosity	1 year
1st Phalanx	Proximal	13-15 months
Humerus	Distal	15-18 months
Radius	Proximal	15-18 months
Metacarpal	Distal	15-18 months
Metatarsal	Distal	16-20 months
Pelvis	Acetabulum	1 ½ -2 years
Tibia	Distal	20-24 months
Calcaneum	Tuber Calcis	3 years
Femur	Proximal	3-3 ½ years
Humerus	Proximal	3-3 ½ years
Femur	Distal	3-3 ½ years
Tibia	Proximal	3-3 ½ years
Ulna	Olecranon	3 ½ years
Radius	Proximal	3 ½ years

Whilst the current research is not directed towards unfused bones, it is possible that some bones from skeletally immature individuals will, inadvertently, be studied. This is because it will not be possible to tell entirely whether isolated finds of early fusing elements are from mature or immature individuals. Change can also take place after maturity has been reached by remodelling, and whilst this does not affect the length of the bones it leads to a greater robusticity. In addition, ossification of ligaments and tendons, exaggeration of muscle insertions and the obliteration of sutures, all take place after maturity is reached and can be a response to injury or stress or just advancing age. Therefore size distributions of relatively early fusing elements may show a 'tail' of smaller individuals that are not represented in the distribution of late-fusing elements in the same population.

The skulls of adult mammals are more elongated compared with those of juveniles, particularly in the facial region, due to the eruption of additional teeth. Independent verification of age of a whole skeleton can therefore be gained from studying the eruption and wear of the teeth. Whilst Table 2.2 gives the tooth eruption data for horses, Levine (1982) has found that there is very little variability between equid species; studies of zebras and onagers produced similar timings. Therefore it is not unreasonable to use this as a guide for donkeys and mules, in the absence of more accurate data. Upper and lower dentitions erupt at slightly different times, but these generally overlap, so the ranges given in Table 2.2 allow for this.

Table 2.2. Ages at which horse teeth erupt (from Levine 1982). Di = deciduous incisor, I = permanent incisor, C = canine, DP = deciduous premolar, P = permanent premolar, M = permanent molar

Once all the permanent dentition has erupted and is in wear, ageing the animal is more difficult. The ageing of horses from their incisors has been practised since ancient times, as the writings of Varro (*r.r.*) show (see Chapter 1) and this gives us a check on whether modern horses differ significantly from Roman ones in terms of rate of ageing. The slight drawback with this is that it is not always clear which tooth is being discussed in the ancient texts. Table 2.3 gives a description of the appearance of the incisors through the animal's life with a note on whether the modern and ancient sources agree; in general this is the case, indicating that the teeth erupted at similar ages in Roman times as they do now. This confirms Silver's (1969) comment (above) that the rate of development in the horse has not increased much in recent times. In addition, teeth evolution is generally slower than that of bones.

The later stages in an equid's life, 15 years onwards, are very variable and are determined to a great extent by the diet of the animal, a coarser diet leading to more rapid wear. These are the stages at which unscrupulous horse dealers will alter the teeth by burning false infundibula and filing the angle of the teeth to make the animals appear younger than thaey are, a practice that is seemingly as ancient as horse dealing (Varro *r.r.* and Columella *r.r.*)!

*Table 2.3. Description of incisor eruption and wear in horses (from Silver 1969 and Webber 1991) with notes from Varro (*r.r. *II, VII, 2-3). For abbreviations see Table 2.2*

Age	Description	Notes from Varro
Birth-5 months	Di1 erupt at birth, Di2 by 5months	
5-12 months	Di1 and Di2 in wear, Di3 erupt	
1-2 years	All Dis in wear	
2.5 years	Di1s lost, I1s erupt	Says the same
3 years	I1s in wear	
3.5 years	Di2s lost and I2s erupt, canines can erupt this early	Says beginning of 4th year
4 years	I2s in wear, canines erupt	Mentions canines
5 years	Di3s lost and replaced by I3s, canines can erupt this late	Says the same
6 years	Infundibulum on I1s becoming smaller	Mentions shrinking of hollows(infundibulum) in teeth
7 years	Infundibulum on I2s also smaller and '7year hook' on upper I3s	Says that this is the limit of accurately telling a horses age
8 years	Infundibulum small in all Is, '7year hook' mainly gone	
10 years	'Galvayne's groove' appears at top of I3s, infundibula almost gone	
15 years	'Galvayne's groove' has reached halfway down I3s, infundibula gone, sometimes '7year hook' returns between 13 and 15 as occlusal surface of all Is becomes more triangular rather than oval as angle of teeth alters	Mentions teeth becoming prominent (ie angle changes) around this time
20 years	'Galvayne's groove' reaches occlusal surface of I3s, gaps appear at tops of teeth, where narrow roots are emerging	
25 years	'Galvayne's groove' gone	
30 years	All Is very sloping with triangular occlusal surfaces, obvious gaps at tops of teeth.	

It is unlikely that many horses lived beyond 20 years in the Roman period, as Varro *(r.r.)* does not mention what the teeth of aged animals looked like. Twenty is about the natural life expectancy of equids in general (Levine 1982), although some can live up to about 40 years. With modern horses, native ponies tend to live longer than the more refined horse breeds, perhaps because they mature more slowly, which in feral populations may be due to a low plane of nutrition. Roman horses are thought to have matured at a rate similar to the native ponies rather than Thoroughbred racehorses (Peters 1998).

In addition to looking at the wear on the incisors, the wear on the cheek teeth can also be used to determine age. This is a reasonable proposition for archaeological bones but it is not generally mentioned in classical texts because of the difficulties of looking at the cheek teeth in a live animal. The method of correlating the height of the tooth (and therefore degree of wear) with age was established by Levine (1982). The problems are that for loose teeth the tooth has to be anatomically identified correctly first and if you are lucky enough to have a whole mandible then the teeth have to be removed or a radiograph produced in order to measure them.

The height of the tooth (from the cemento-enamel junction at the roots to the occlusal surface) displays an exponential decay with increased age (Levine 1982). The rate of decay is fastest from when the tooth comes into wear until the age of around 10, and then the rate declines to almost no wear by around 17 years old. This means that in a 'natural' population with a life expectancy of 20, the teeth would last throughout the life of the individual (as would be expected). However, the method of Levine (1982) has another drawback; the wear curves are based on data from one size of horse (New Forest), so teeth from larger or smaller individuals cannot be directly compared with the curves as the measurements will be different. As it is usually impossible to know whether archaeological teeth are from that size of individual or not it makes the system inaccurate and it can therefore only be used as a general guide to the age of an individual.

Whilst it is possible to tell the age of archaeological horse material quite accurately up to the age of about 7 years by looking at both epiphyseal fusion and tooth eruption and wear, when all the epiphyses are closed and the teeth erupted it becomes much more difficult and subjective. However, in terms of how age affects bone growth this is not an issue as by that point bone growth has stopped, both longitudinally and in circumference, except in response to stress, injury or disease.

All these ageing methods are of most use when a whole skeleton is present, as a combination of the methods can usually estimate the age at death quite accurately. Therefore, if some bones (i.e. metapodials) are fused but others (i.e. femur) are not then the animal is not mature, and it is possible that circumferential growth of the early fusing bones has not fully progressed. However, if isolated metapodials are found, it is impossible to say if they are from an individual that is fully skeletally mature, which could cause problems in the interpretation of data from archaeological contexts. For instance, if slenderness indices (shaft breadth / length x 100) are produced for the metapodials, it is not possible to know whether very slender bones are from young individuals or from mature animals with slender limbs. It is hoped that this problem will (at least partly) be overcome by studying the proportions of the bones of fully mature whole skeletons and producing a range of variation for comparison with isolated finds.

All these ageing methods are based on horses and there appears to be no specific information available to compare the timing of epiphyseal closure and tooth eruption of donkeys and mules with those outlined above horses. Therefore, for this study it has been assumed that there is little difference, although it should be borne in mind that this might not be the case. Further work on this subject would require an extensive collection of complete skeletons with precisely known ages at death. Given the expense of obtaining such a collection a study of this nature is unlikely to occur, unless advances can be made in the use of X-rays for determining the state of epiphyseal fusion.

2.4.2 Sex

The identification of archaeological bones to male, female or castrate (gelding) is very difficult. If the jaws are present this is made easier as well-developed canines (or tushes) are present in all male equids (including geldings) but are rarely present in mares, and then usually in a reduced form. In horses the canines erupt at around 4 years old (Webber 1991). This is one way of distinguishing adult males from females, although it is not 100% reliable. In addition, the pelves of male and female equids differ, as they do for most mammals, in order to allow the female to give birth. However, it is very rare to find intact pelves in archaeological material, making this a less useful method of determining sex.

Moving on to the post-cranial skeleton (except the pelves), the way in which bone growth is affected by sex can provide us some clues. Sex can affect growth in two ways: the direct effect of the genetic sex of the individual and the indirect effect of sex hormones (see Sections 2.4.4).

In many mammals there is a noticeable difference in height and weight between males and females. This is termed sexual dimorphism and is quite easy to detect in a population of wild animals, where the degree of size variation between individuals is relatively small. However, in populations of domestic mammals the size differences due to sexual dimorphism can easily be masked by the size variation in diverse breeds or demes. This is particularly true for archaeological material where it is very difficult (if not impossible) to attribute individual bones to sex, and therefore size of the bones is the only method of separation.

In horses there is 'no appreciable difference between the sexes at birth nor up to 17 months, but thereafter males grow faster than females' (Pomeroy 1955). This faster growth however, is more related to gain in weight rather than height. Therefore, there is still not a great difference in height at maturity between entire males and females (Pomeroy 1955; von den Driesch and Boessneck 1974; Bartosiewicz *pers. comm.*). The question of the growth of castrates is an issue that has not been well studied in horses and may cause a further small degree of sexual dimorphism (see below). However, it is likely that the overlap between the three groups is still so great (extrapolated from Davis 2000 for sheep) that it is not likely to cause confusion when looking for differences between archaeologically determined groups in the results of the withers height analyses in this study. There are however, differences between stallions, mares and geldings in terms of bone robusticity and skeletal proportions (see below) that will be important to consider when analysing the results of shape index and log-ratio calculations (Sections 6.3 and 6.4).

Because different parts of the body do not grow at a uniform rate, the differences in size between sexes results in different body proportions. Some differences are caused indirectly by differences in metabolism during growth. Growth in males is affected by poor nutrition to a greater extent than in females, with castrates being intermediate (Pálsson 1955). This is due to the fact that colts (male horses under 3 years old) maintain a higher growth rate than fillies (female horses under 3 years old) from 12 months onwards (Breuer 1996), and therefore develop a greater robusticity by the time growth ceases. Entire males gain weight faster than females after weaning, but then proceed further in the development of the late maturing parts than the females. Pálsson (1955) suggests that stallions are not only larger in almost all body dimensions than mares, but all their measurements (except in the pelvic region) are better developed in proportion to the height at the withers. Females generally mature before males, hence the further development of the late maturing parts in stallions.

Castration reduces the difference between the sexes even further. From birth to 5 years the body measurements of geldings increase more than those of mares, the difference being greatest in the depth and width of the chest and smallest in the circumference of the metatarsals and knees and in the withers height. In addition, the bones of geldings do not develop to the same extent in thickness as an entire male, but the length growth is un-retarded. Males castrated young do not develop secondary sex characters such as a crested neck and also do not attain the broad head, thick and heavy neck, or heavily muscled fore- and hindquarters that typify an entire male (Pálsson 1955).

There appears to have been very little experimental work carried out on the physiological effects of castration on horses, and almost none on the effects on the skeleton and its growth. This is most likely because the horse is very expensive to use as an experimental animal. The effects of castration on the skeletons of other domestic mammals have been studied and most of the following paragraphs are based on studies of sheep (and other animals) and the results extrapolated to horses.

It has been shown that testicular deficiency (mostly lack of testosterone production) seems to delay epiphyseal fusion and hence prolong the growth period and, conversely, the administration of testosterone causes earlier development of ossification centres and the premature closure of epiphyses (Davis 2000). The sequence of epiphyseal closure remains the same for entire males, females and castrates (as outlined above in Section 2.4.1) but the timing of the closures varies. From studies of sheep skeletons, Davis (2000) suggests that females fuse earliest, followed by entire males, and the castrates are much delayed. However, the lack of experimental work on horses means that it is not known whether this delay falls at the upper limit or extends outside the age range given in Table 2.1.

The age at which castration takes place determines to some extent what the effects on skeletal growth will be, because the increase in the length of the growth period will only affect those bones whose growth zones are still active at the time of castration (Davis 2000). For instance, if the animal is mature when gelded then obviously skeletal growth will not be affected, but perhaps remodelling due to a reduction in muscle mass as a result of the drop in testosterone levels could take place. However, as the modern practice is to geld between 6 and 12 months old (usually nearer 12 months, after the effects of weaning have been countered), prior to the colt becoming sexually active, then skeletal growth from that point on will be affected. In a colt gelded at 12 months this would mean that potentially all epiphyses except the glenoid tuberosity of the scapula and the proximal second phalanx could be affected, allowing a great deal of extra length growth in all the limb bones.

There are, however, individuals that are gelded later, and the changes that could still be possible in the growth pattern would be determined by the age at which the gelding took place. For instance, in a colt gelded at 2 ½ years of age the lower limbs would have already fused, so castration would only allow delayed fusion of the distal radius, proximal tibia and humerus and both ends of the femur. In the archaeological record it is difficult to know when castration took place because most bones are found as isolated elements, and even where a whole skeleton is present it would be impossible to determine whether the limb proportions were the result of gelding or the inherent characteristics of a deme.

Roman literature (Section 1.3.1) indicates that gelding took place when a horse was around 4 years old, at which time most of the epiphyses, with the exception of the vertebrae, are fused, and therefore the animal will have the appearance (and skeletal proportions) of a stallion (Peters 1998). In this research it therefore seems that the bones are most likely to exhibit entire male or female patterns of growth in the skeletons, even if some are from individuals gelded after growth had ceased, making it unlikely that sexual dimorphism will cause problems in the analysis of biometric data from horses of the Roman period. However, donkeys and mules may have been castrated earlier. Apsyrtos (quoted in Peters 1998) suggests that donkeys were castrated at two years of age, which would allow delayed fusion of the long bones mentioned above for castration at 2 ½ years (assuming that epiphyseal fusion takes place at similar ages in donkeys as in horses). Although no specific information is available for mules they may also have been castrated earlier than horses (Section 1.3.1).

The type of castration also affects the growth pattern of the skeleton. Two methods known to the Romans included crushing of the spermatic cord and surgical removal of testes. Under the first method, the production of testosterone will not be halted so the animal should grow like an entire stallion. Removing the testes, however, will halt testosterone production and the animal will grow more like a female but with differences due to the lack of oestrogen production (Section 2.4.4). Roman literature suggests both methods were used on animals, but it is unclear if both were practised on horses. Certainly surgical removal of testes was used on horses, as the process is described in great detail in both the *Mulomedicina chironis* and the *Corpus hippiatricorum Graecorum* (Sections 1.3.1 and 1.3.3). Therefore, if the males were castrated before long bone growth has ceased, the full effects of testicular deficiency would be detectable.

For sheep, Davis (2000) suggests that the best biometric separation of all three sex groups can be obtained by plotting bone length (Gl) against shaft slenderness (SD) for the metapodials. Although this does not produce clear-cut separation of the three groups, most of the specimens are in different regions of the graph. This means that whilst it is unlikely that individual bones can be attributed to sex, a plot of a sample of measurements should reveal whether all three groups are present or one is more abundant. It should be noted here that this was based on a single breed of sheep and that the picture becomes less clear if more than one breed is included in the sample, even to the point of reversing the groups (T. P. O'Connor *pers. comm.*). This method may also not be applicable to horses as the degree of sexual dimorphism is probably less than in sheep. However, it is impossible to know for sure unless a large, adequately aged and sexed collection of horse skeletons (preferably of a single breed) can be brought together for analysis. As can be seen in Chapter 5 many of the horse skeletons in reference collections have no age or sex data recorded and are of very varied breeds, so analysis of this method could not be carried out during this research.

Some of the measurements analysed by Davis (2000) for sheep showed no significant differences between the sex groups and were independent of age differences, and therefore would be useful as indicators of body size. These include HTC on the humerus, BFd on the metapodials and Bd on the tibia (see Chapter 3 for an explanation of the measurement codes). These measurements were taken on the equid bones for this research, but again the lack of an ideal collection of modern reference data precludes any analysis of whether the same measurements are also sex and age independent in equids.

2.4.3 Nutrition

Nutrition obviously plays a crucial role in growth, as it requires an increased level of many substances that are provided by the diet of an animal. A maintenance level of nutrition provides enough nutrient intake to maintain the body as it is. This level varies considerably between individuals as it depends on metabolic rate, size, sex, climate, reproductive status and the work expected of the animal (Pilliner 1992). A high plane of nutrition provides enough extra nutrients to allow for growth above the maintenance level. A low plane of nutrition does not provide enough nutrients for maintenance of the body, and the body will use reserves of fat and protein to keep going, resulting in weight loss. At the maintenance level it has been noted that whilst weight gain stops, skeletal growth continues (Pomeroy 1955; Duren 1996).

The critical nutrients required for growth in different animals are basically similar, i.e. energy, protein, minerals and vitamins. However, the specific nutrients needed for a balanced diet in various animals is very different (Duren 1996). Because horses vary so widely it is difficult to discuss their nutrient requirements as a whole, and the problem is compounded by the fact that a horse is an expensive experimental animal and little experimental work has thus been carried out on its nutrient requirements (Pilliner 1992). The exception to this is the Thoroughbred racehorse, but it is not a good analogue for archaeological horses.

The most critical nutrients for growth in young horses are energy, protein (lysine in particular), calcium, phosphorous, copper and zinc (Duren 1996). In the natural environment the horse has developed evolutionarily to be an efficient enough converter of food to allow it to survive the winter when forage is in short supply. However, under domestication the horse has been bred for performance and not for its efficiency of food conversion, with the result that highly refined horses such as thoroughbreds are far less efficient at converting food than the native ponies, leading to their nutrient intake having to be proportionately much higher (Pilliner 1992). Size in terms of nutrient requirements is more closely related to body weight than to height, for instance a 14.2 hh show pony weighs less than a 14.2 hh cob (Table 2.4). The approximate maintenance level of energy that is required by horses of different weights is given in megajoules (1 million joules) of digestible energy per day (Table 2.4). Table 2.4 also shows the extra requirement for maintenance during work. Light work is defined as an hour's walking up to an hour of fast trotting, cantering and some jumping per day; hard work is defined as more than an hour's cantering, galloping and jumping, racing and polo, and up to 100 km endurance work. The variation in these energy requirements depends on the individual horse (Pilliner 1992).

Table 2.4. Height, body weight and approximate nutrient requirements for different types of horses and ponies (from Pilliner 1992)

In addition, horses require a certain level of protein intake for maintenance; at rest this is about 7.5-8% crude protein in the diet. Usually, if the energy requirements are being met, the protein level will also be adequate. The protein requirements for work are not much more than those at rest; for hard and fast work the amount only goes up to 10% crude protein in the diet (Pilliner 1992). The amino acid most important to growth is lysine, so the correct levels of this in the protein intake of young horses is vital. If the lysine level is met, then other necessary amino acid levels will usually also be available in sufficient quantities (Breuer 1996). Lysine is present in high concentrations in legumes, so concentrated feeds containing beans will contain adequate supplies. It is known that the Romans feed lucerne and beans (both legumes) to horses (Section 1.3.1), so it is likely that the lysine requirements of growing horses would have been met.

In terms of fodder, for most horses at rest and in light to medium work good quality hay can fulfil the dietary requirements for maintenance. One kilogram of good quality hay can provide about 8 MJ of energy (and enough protein), so that for a 1320 mm pony 4.5 to 5.5 kg of hay per day will be sufficient at rest, and similarly for a 1520 mm horse 6.5 to 8 kg of hay is enough (Pilliner 1992). However, as the rate or duration of work increases there comes a point when the horse cannot physically eat enough hay to provide the nutrients, and therefore supplementary feeding of higher energy and protein foods is necessary. For instance, a marching army cannot stop to allow the horses to graze, so supplementary feeding is essential and the Roman army certainly carried this out (see Section 1.3.1).

Nutrition of the mare during pregnancy and lactation, and the foal both before and after weaning, are very important for both the maintenance of the mare and the growth of the foal. During the 11 - month gestation there are two periods with different requirements. During the first 8 months the foetus grows very little and the mare requires no more nutrients than she would if not pregnant. However, during the last three months the foetus grows a considerable amount and the mare's energy requirement goes up to that of a horse in light to medium work, and the protein requirement to that of a horse in hard work. This means that the mare will most likely have to be fed concentrated feed in the last 3 months to bring the protein level up high enough. During lactation the energy requirements of the mare increase to the level of a horse in medium to hard work and the protein requirements are even higher than during late pregnancy, because the milk is high in protein (Pilliner 1992).

Table 2.5. The relationship between body weight and height during growth (from Pilliner 1992)

Breed	**Age**	**Height (mm)**	**Weight (kg)**
Pony	2 months	910	60
	4 months	1020	80
	9 months	1170	140
	12 months	1220	180
	3 years	1320	320
Thoroughbred	Birth	1020	50
	6-8 weeks	1120	90
	8-12 weeks	1220	140
	4-6 months	1320	200
	9-12 months	1470	350
	2-3 years	1570	450

The nutrient requirements of growth change through time, particularly as the rate of growth slows towards maturity. Birth weight in very important in determining the horse's mature weight and a foal weighing less than 35 kg is unlikely to grow to more than 1520 mm high. At birth a foal is about 10% of its adult weight and should reach 50% of mature weight by weaning (Breuer 1996). By 12 months the young horse should achieve 60 to 70% of its mature weight and about 90% of its height (Pilliner 1992). Table 2.5 shows the relationship between body weight and height during growth.

The mare's milk will provide the ideal diet for a young foal, but as it gets older good pasture can provide significant amounts of nutrients (Breuer 1996). After weaning it is likely that the foal will require concentrated feed as well as hay or grass to provide enough protein to maintain the level of growth. This level of growth can be a gain of 1 kg per day from 3 to 6 months, then 0.5 kg per day until 12 months for a horse expected to mature at 450-500 kg (Pilliner 1992), which means a need for about 16% crude protein in the diet. Supplemental feed will therefore be at about 1% of body weight prior to weaning and around 3% afterwards (Breuer 1996). Because bone is one of the early maturing tissues, the foal requires a diet rich in protein and calcium (amongst other minerals and vitamins). As bone growth slows and is replaced by muscle growth, the young horse requires a more carbohydrate-rich diet. However, it is not good to allow growth to proceed too rapidly as this can lead to developmental problems such as are often seen in racing Thoroughbreds that have to been grown very fast to race at 2 years old (see Section 2.4.7).

Some information on the diet of young horses and also on the supplementary feeding of pregnant and lactating mares is given in the Roman literature (see Section 1.3.1) and this suggests that young horses, particularly those bred on the large stud farms, in the Roman period were probably adequately provided with the basic nutrients to sustain growth. Similarly, the variety and quantities of feedstuffs supplied to equids in work (see Section 1.3.1) suggests that at least those used by the army, as racehorses and by the upper strata of society were able to sustain nutrition and work to the level required. As with all societies, the lower strata may have had enough trouble feeding themselves let alone their animals, and the starving state of mill beasts described in several texts (see Section 1.3.1) attests to this fact.

Vitamins (particularly A, C, D and K) play significant roles in the development and maintenance of bone. Although not much work has been done on the sub-clinical effects of vitamin deficiencies (i.e. not severe enough to produce a 'disease'), they are known to retard growth (Pomeroy 1955). By looking at the ways each vitamin works, the effects of a deficiency can be implied. In cartilage vitamin A is required for the release of lysosomal enzymes and the extracellular digestion of glycoproteins, whilst in bone it increases the number and level of activity of osteoclasts. Therefore during growth vitamin A deficiency will impair the process of turning cartilage into bone and will also decrease the rate of remodelling, possibly resulting in oddly shaped bones. In adult bone a lack of osteoclast activity could lead to weakening of the bone, where necrosis occurs and cannot be removed and reformed.

Vitamin C is essential for the proper synthesis and aggregation of collagen, so a deficiency will lead to the production of fragile and weakly aggregated collagen fibrils and hence weak bone.

Vitamin D affects bone indirectly as it regulates the absorption of calcium and phosphate in the intestines and kidneys. Therefore vitamin D deficiency (rickets) causes a low concentration of calcium and phosphate ions in the plasma and hence calcification of cartilage cannot take place. Poorly mineralised bones are formed that cannot support the weight of the body, and they become characteristically bowed. Vitamin D may also promote bone resorption either alone or in conjunction with parathyroid hormone (PTH; see section 2.4.4).

Vitamin K is essential for the synthesis of osteocalcin, a phylogenetically variable protein that binds to hydroxyapatite crystals and to calcium phosphate. Osteocalcin is an essential part of the bone mineralisation process, so a vitamin K deficiency will detrimentally affect this process.

Minerals are also important for normal bone growth to occur, the most obvious being calcium. However, other minerals, such as phosphorus, copper and zinc, are also required. Calcium deficiency can lead to disease (see Section 2.4.7) and malformation or stunted growth of the whole skeleton, because it causes poor mineralization of bone. However, it is not just calcium that is critical, a balance between calcium and phosphorus has to be maintained for normal growth (Hintz 1996). An excess of phosphorus over calcium will interfere with calcium absorption, whereas a deficiency of phosphorus results in bone demineralisation (Duren 1996). It has been estimated that horses with a body weight of 500 to 600 kg need about 20 to 24 g of calcium per day for maintenance. Brood mares (same body weight) require 35 to 37 g per day in late pregnancy, and this increases to 50 to 56 g during early lactation. Young horses, 4 to 12 months old (expected to mature at 500 to 600 kg) need 36 to 45 g of calcium per day. Phosphorus requirements are less at 15 to18 g per day for maintenance, 23 to 28 g for pregnant mares, 23 to 28 g for mares during lactation and 24 to 30 g for weaned foals and yearlings.

The trace elements such as copper and zinc, although required in less quantity, are still vital for normal growth. Low copper intake can result in inferior collagen quality, biomechanically weak cartilage, decreased bone density and osteochondrosis legions (Hintz 1996). This is because the enzymes involved in elastin and collagen formation are dependant on copper (Duren 1996). It is estimated that around 50 to 80 mg per day are required for weaned foals and yearlings. Zinc is required by many metalloenzymes that are involved in protein and carbohydrate metabolism, so is vital for many areas of growth (Duren 1996). Weaned foals and yearlings require about 200 to 300 mg of zinc per day to maintain growth rates. Horses at pasture, with little or no supplementary feeding, will often lick the soil in certain areas in order to try and obtain the minerals that the grass is lacking.

Under-nutrition causes the physiological age of an individual to proceed at a slower rate than its chronological age. Therefore, in most cases, the body is able to 'catch up' growth after a period of malnutrition because the growth period has been extended. Animals show great flexibility in recovering, but if the period of malnutrition occurs early in life and is sufficiently prolonged and severe, it may result in permanent stunting of growth (Pomeroy 1955).

Restricted nutrition at any age does not just retard growth in general but affects different parts of the body and tissues differently. An animal's form can be controlled by changing the plane of nutrition at different stages of growth, a fact that has been exploited by the commercial meat industry to provide fat or lean animals for slaughter depending on current tastes (Pálsson 1955). It is even exploited by the Thoroughbred racing industry to some extent by ensuring that foals receive maximum nutrition during late foetal and early post-natal life to ensure the lower limbs reach their genetic potential in length and hence enhance their speed later on. This control of growth takes place within the wide limits imposed by genetic capacity on one hand and under-nutrition resulting in starvation on the other (Pálsson 1955).

In general (taken from Pálsson 1955: 475):
1) Malnutrition of the dam only affects the foetus in the later stages of pregnancy
2) During growth, the parts most affected by a period of malnutrition will be those at their highest growth intensity
3) A period of malnutrition at any age will affect the earliest maturing parts the least and the latest maturing ones the most
4) When the level is sub-maintenance, tissues are used for energy and protein in reverse maturing order, i.e. fat first, then muscle, then bone, and in the latest maturing regions of the body first (loin and pelvis)
5) Any part that has been retarded has great ability to recover once nutrition is increased, provided it has not gone on too long or at too severe a level

In view of these statements, the later developing growth in the thickness of the bones is retarded by poor nutrition to a greater extent than the early developing length growth. The length growth can be affected for example in the metapodials by a late foetal deprivation. This is because there is not enough time before the bone matures to catch-up the growth lost at that stage. The shape of the bones is more affected by different planes of nutrition than their weight. Early maturing distal limb bones are less affected than the later maturing proximal and girdle bones. In horses the length of the lower limb bones is more severely affected by late foetal deprivation because of the longer gestation period and therefore higher growth intensity of the bones at that stage than in other mammals.

Therefore, in summary, a constant high plane of nutrition means that nutrition ceases to be the limiting factor in growth: genetic potential is then the barrier. In terms of archaeological bones, the effects of malnutrition can be particularly hard to detect unless there are chronic shortages of particular parts of the diet leading to deficiency syndromes (see above) or the level of nutrition has been very low or maintained over a long period of time and the system has not recovered once the level is increased.

For whole skeletons it might be possible to suggest that abnormal limb proportions could be the result of malnutrition during growth. However, it would be difficult to differentiate between differences due to sexual dimorphism, inter-deme variation and malnutrition unless the effects were severe. For both whole skeletons and isolated bones, the fact that circumferential growth of bones is more severely affected by malnutrition than length growth may be detectable on archaeological bones. For instance, low values for the shape indices but no discernible differences in withers heights may indicate malnutrition during the growth period.

2.4.4 Hormones

Four hormones can influence skeletal growth: growth hormone, thyroid hormone, sex hormones and glucocorticoids. Growth hormone (Somatotropin) increases the synthesis of DNA (deoxy-ribonucleic acid), RNA (ribonucleic acid) and proteins, which leads to an increase in cartilage growth. It is released from the anterior pituitary gland and is controlled by the hypothalamus. Thyroid-stimulating hormone (also produced in the anterior pituitary gland) affects skeletal growth by promoting the differentiation and maturation of bone cells. Therefore the combination of growth hormone and thyroid-stimulating hormone maintains the rate and sequence of both endochondral and intramembranous bone formation (Bouvier 1989).

Too much or too little somatotropin can lead to acromegaly (gigantism) or pituitary dwarfism, respectively. This means that the individual is larger or smaller than usual but maintains the correct body and limb proportions (Bouvier 1989). Too little thyroid-stimulating hormone leads to thyroid dwarfism, in which the individual retains infantile body and limb proportions and is also mentally retarded; in less severe cases it just causes retardation in growth. Hyperthyroidism can lead to a loss of weight through an increased metabolic rate but also enhances growth of tissues (Pomeroy 1955).

Glucocorticoids (produced in the adrenal cortex) inhibit skeletal growth by decreasing DNA, RNA and protein synthesis. They may also interfere with mineralisation by impairing calcium absorption in the intestines. Hence they have the opposite effect to growth hormone (Bouvier 1989; Saladin 1998). Just prior to maturity the adrenal cortex increases in size, with the effect that the increased glucocorticoid production is responsible for bringing growth to a standstill (Pomeroy 1955).

Sex hormones are instrumental in causing the growth spurt that occurs at puberty in humans. Whilst the smooth growth curves suggest this spurt does not occur in ungulates (Pálsson 1955), sex hormones have other effects on growth. In females, oestrogen (produced in the ovaries) influences the epiphyseal plate closure at puberty and also maintains the skeletal mineral mass (Bouvier 1989). Therefore an excess of (or prolonged exposure to) oestrogen during growth can inhibit skeletal length growth by causing early ossification of the epipyseal cartilages (Pomeroy 1955). A lack of oestrogen during growth results in an increased bone growth over a prolonged period. Also, a lack of oestrogen after maturity can cause loss of bone mineral and lead to osteoporosis. Progesterone will also increase growth (Pomeroy 1955). Testosterone (produced in large amounts by the testes in males and small amounts by the ovaries in females) influences growth in both length and width of bones, by directly activating osteoblasts and chondroblasts and indirectly through its effect on muscle development (Bouvier 1989). However, testosterone has no effect on the rate of growth (Pomeroy 1955).

Hormones also have an influence on the turnover of skeletal tissues. Two hormones act in opposition to do this, parathyroid hormone (PTH) raises plasma calcium levels and calcitonin lowers it. PTH raises plasma calcium by increasing the rate of calcium reabsorption and hydroxylation of vitamin D in the kidneys. At high levels it also stimulates osteoclastic resorption of bone. Calcitonin depresses the activity of osteoclasts, resulting in lowered calcium levels and protection of the skeleton from excessive PTH activity. An imbalance in these hormones can cause either excessive resorption or formation of bone tissue during growth and adulthood (Bouvier 1989).

Once again, the effects of hormones on the growth of bones would be very hard to detect zooarchaeologically, unless the cases were particularly extreme. Even then the distinction between the effects of hormones and, for instance, vitamin or mineral deficiencies would be difficult to achieve.

2.4.5 Genetic potential

No matter how well the animal is fed there is a genetically set limit, past which an individual cannot grow. This is mostly determined by the size of the parents, and in particular the mother (see below). If a mare and stallion of equal height of the same breed, both of whom have been raised to their genetic potential, were mated, the resulting foal should mature at approximately the same size as the parents. However, when breeding a mare and jackass, the resulting mule foal will mature at the same size or taller than the dam. Joan Rawley (a mule breeder in Tennessee, USA) says that her mules, bred from a 1395 mm Spanish jackas and Paso Fino mares around 1520 mm, are slightly over 1520 mmh at maturity (J. Rawley *pers. comm.*). Following a question posed on their Internet forum, members of the British Mule Society (http://www.britishmulesociety.org.uk) suggest that mules can mature at up to 10 cm taller than their dam. This is most likely the result of hybrid vigour, although it is possible that the late-fusing epiphyses of mules close later than horses, giving a longer growth period. This would lead to a long and slender conformation of the late maturing bones such as the femur and tibia. This hypothesis cannot be tested at present because of the lack of mule skeletons available for study in reference collections (see Chapters 3 and 4).

When breeding horses, the size of the mare is of importance in allowing the genetic potential to be reached because the size of the dam limits the size of the foetus. The maternal influence can suppress the genetic influence of the male, so that birth can take place. For instance, when a Shetland pony is crossed with a Shire horse, the foal from the Shire mare is three times as large as that from the Shetland mare. Also each foal resembles a purebred foal of the dam's breed more than from the sire's. The differences decrease in post-natal life but do not disappear entirely (Pálsson 1955). Therefore to breed for maximum size, the largest stallions should be bred to the largest mares, and the offspring will be as large as the size of the dam allows.

The age of the mare can also have an influence on the offspring reaching its genetic potential. A young mare will produce a smaller foal than a mature mare. The reason is that when the mare is not fully mature, her nutritional needs for growth compete with those of the foetus, meaning that neither is receiving the maximum amount. Older mares also tend to produce smaller foals, particularly if they have been extensively bred from (Pálsson 1955). Varro (see Section 1.3.1) recommended that mares be bred from between the ages of three and ten years. In modern studs, three is also usually the minimum age but more often the mares are left until four as the body is more mature then. With modern stud practices, fertility and ease of conception in the mares can be kept into older age, allowing them to be usefully bred from for longer than in the past: into their teens is quite normal.

Genetic potential can be affected by many factors, mostly those that affect growth in general, but there are other factors relating to the dam that can stop a foal from reaching its genetic potential in terms of size. As has already been mentioned, the nutrition of the dam, particularly in the later stages of pregnancy and whilst lactating, can affect the growth of the foal, particularly in relation to the growth of its metapodials (see Section 2.4.3). In addition, nutrient restrictions of the growing horse can affect the expression of genetic potential in terms of size and structure. For instance, a low protein but high carbohydrate diet could change the composition of growth to more fat and less muscle or bone, resulting in an animal that does not reach its genetic potential in terms of height and muscle development but is obese (Breuer 1996).

Improved breeds have a proportionally more advanced state of development of the later maturing parts than their wild ancestors, the latter resembling a juvenile form of the improved breed. Early maturity and advanced development are inheritable characteristics provided the level of nutrition is sufficiently high. The evolution of horses has been along two lines: animals for speed and animals for draught. Thoroughbreds, bred for speed, have an increased leg length in proportion to the depth of the body, whilst draught horses have been bred along lines much more similar to those of beef cattle, breeding for more advanced development of the late maturing hindquarters (Pálsson 1955).

The inheritance of physical traits is one that the Roman writers hypothesised upon extensively but could know little of the science behind the process. This was because it was only in the 19th century AD that Charles Darwin published his *On the Origin of Species* and Gregor Mendel undertook his pioneering work on the inheritance of physical traits. And only in the 20th century AD were genes and DNA discovered: research continues in an attempt to fully understand them. Whilst the Greeks considered the mare's attributes paramount in imparting the physical characteristics to the offspring, the Romans thought it was the stallion. With modern knowledge it is, of course, now known that the offspring inherit a combination of characteristics from both parents. There are, however, some stallions that seem to regularly impart certain characteristics to their offspring, regardless of the characteristics of the mare (and *vice versa*), and these are termed 'pre-potent' (Mortimer 2004). It is also still true that a single stallion can more quickly change the characteristics of a group of horses than a mare, because it can produce more offspring per year than a mare. Therefore this was the standard method of breeding for a purpose or generally improving stock that the Romans employed, as it is today.

The inheritance of temperament is one that is much debated in relation to human children at present, with 'nature or nurture' comparisons being undertaken (Winston 2004). With horses it is generally acknowledged that a calm, placid mare, that is well used to being handled by, and willingly associates with, her human handlers, will produce a foal that is likewise not afraid of human contact. However, the temperament of the foal is also at least partly genetically determined; its reactions to danger and new situations are mostly governed by in-built reactions until learning allows modification of those reactions. In terms of horses for different uses, an inherently placid horse is desirable for general riding and draught use, whilst a fiery, reactive horse is more suited to the cavalry and a horse with a highly tuned 'flight' response will do well in racing. These characteristics were believed by the Romans to be inheritable and hence horses were bred accordingly.

2.4.6 Exercise

The effect of exercise on growth of the skeleton is something that probably does not receive the attention it should in modern literature except, in relation to modern racehorses. This is perhaps because it is presumed that those working in the field know that a horse should not be broken in and worked until it is mature enough. However, the term 'mature enough' may not relate to skeletal maturity. For instance, it is usual practice for horses (other than racehorses) to be broken in at three years of age (Knowles 1993), at which point their skeletons are not fully mature, although nearly so.

Modern racehorses are broken in at 18 months so that they can be raced at two years old. This is of course when the skeleton is quite immature, hence the weight limits for the jockeys and the use of very lightweight saddles, etc. Even with these restrictions it is quite often the case that racehorses suffer from skeletal defects resulting from overstressing the limbs during the growth period. For instance, fractures of the epiphyses are a regular occurrence, as are osteochondritis dessicans lesions caused by damage to the growing joint cartilages (Section 2.4.7).

However, Roman practice was to break in most equids at three years old, as it is today (aee Section 1.3.1). Roman racehorses were left until four years, because it was considered (quite correctly) that these animals should be more mature to withstand the extra strain in the circus. Therefore, it is unlikely that exercise relating to breaking in immature animals would be affecting the skeletal growth of Roman horses. The most likely cause of exercise affecting the skeleton would be the result of injury during work that resulted in a pathological change to the bones, and this is dealt with in Section 2.4.7 below.

Therefore, for the purposes of this study it is unlikely that changes caused by exercise would affect the measurements of limb bones, as most damage occurring during growth or afterwards would show up as a pathological case, and such bones would not usually be measured.

2.4.7 Disease and pathology

Bone disease in general is too large a topic to cover here. This section will be restricted to those diseases and conditions that affect the growth of bones or their size and shape, as these have relevance to this research. In many cases the aetiology of the diseases is poorly understood, making their prevention difficult and only allowing treatment of the symptoms even with modern veterinary advances. Therefore quite advanced cases are noted from many archaeological sites. Some of these diseases are thought to be attributable to poor diet and others to genetic mutations. Also included in this section are other pathological conditions seen on bones that result from some form of trauma.

Whilst the diseases and pathological conditions discussed below can drastically affect skeletal growth, and/or the size and shape of adult bones, in their more advanced forms, in general mild cases will not produce noticeable effects on the skeleton. In terms of this research, the more advanced cases of these conditions should have been noted as pathological by the zooarchaeologists working on the material and for that reason these bones will probably not have been measured and therefore will not bias the biometric sample. However, mild forms of these conditions are rather difficult to detect and so measured examples could affect a biometric sample, although these would be unlikely to introduce much bias as the measurements would not be sufficiently different from normal variation.

However, as Baker and Brothwell (1980) state, ‘what is normal?’, when studying the skeletons of domestic animals that have been selectively bred for particular characteristics, and may appear quite abnormal in relation to their wild ancestors. This is true of achondroplasia, the genetic form of dwarfism, where the head and trunk grow normally but the limbs are greatly shortened. In humans this is the most common form of dwarfism. Dexter cattle are often heterozygous for a form of achondroplasia, so an appreciable number of pure Dexter calves are homozygous achondroplastic dwarves or ‘bulldog calves’. Dachshund dogs also have the classic appearance of achondroplastic dwarves, even though their short legs are now considered a breed characteristic rather than a deformity (Baker and Brothwell 1980). Whilst there does not seem to be any literature on this condition in equids, it is likely to occur occasionally, and if the resulting animal was viable there were at least two possible reactions to this in the past: the animal could be immediately killed as a 'monster' or kept as a curiosity.

Other hereditary conditions in horses are known and out of 23 listed by Roberts (1971, quoted but not listed in Baker and Brothwell 1980: 40), eight are considered to affect the skeleton. However, the prevalence of these conditions is unknown because this can only be determined by breeding experiments, which are slow and expensive in large animals such as horses (Baker and Brothwell 1980). Some of these conditions have been noted in archaeological specimens, and whilst they do not affect the measurements, they may be of some use in determining the possible movement of horses to different areas and the question of stock improvement, through the use of prevalence statistics.

The study of these non-metric traits is an area that is receiving more attention but still needs further research. One aspect of interest is consideration of the size, number and position of the nutrient foramina on certain elements. For instance, in cattle the regular recording of size and number of the mental foramina has elucidated some information on the movements of animals (Dobney *et al*. 1996). In equids, a likely candidate for further work appears to be the supra-orbital foramina. Eisenmann (1986) suggests that these could be used as a species determinant, and although this is unlikely (Section 4.3.1) their value in determining horse movements should be explored. Another non-metric trait found in horses is the presence of supernumerary incisors. These have an incidence of around 0.6% in modern horses (Colyer 1936 quoted in Baker and Brothwell 1980), but in the light of evidence that 8th century AD Hungarian folk tales ascribe magical powers to animals that possess these extra teeth, it would be worth considering if the prevalence varies across different time periods and geographic areas and could therefore be related to stock movements.

Baker and Brothwell (1980) wrote that 'the destructive effect of contagious diseases should not be underestimated' and yet this area has perhaps still not received the attention it deserves. In particular, whole skeletons recovered from a site should be studied more often and more carefully as possible evidence of an outbreak of an infectious disease in a particular community. This is particularly true where a number of skeletons of a single (or closely related) species are found in a single burial incident. For instance, Peters (1998) has suggested that the 35 horse and mule skeletons found together in one pit at Weißenburg/*Biriciana* (Germany) are most likely evidence of a fatal epidemic outbreak. The biometric aspects of the analysis of such skeletons will be unaffected by their cause of death, as most infectious diseases kill before changes to the bones can take place.

There are, of course, exceptions to every rule and one such disease is brucellosis. The *Brucella abortus* bacteria does not kill horses, nor cause the reproductive problems seen in cattle, but it does cause changes to the bones of the vertebrae. The cervical and lumbar intervertebral discs are gradually destroyed, resulting in the erosion of the vertebral bodies and the growth of exostoses, eventually leading to ankylosis of the spine.

Other infections that directly affect bones are those that, as a result of trauma or blood-borne agent, cause inflammation of the tissues of the bone itself. These are osteomyelitis (infection starting in the marrow cavity), osteoperiostitis (periosteal origin) and osteitis (cortical origin) (Baker and Brothwell 1980). Of these, the first two are the most commonly found and can result in large lesions that usually spread to involve all three sites if left untreated. Areas specifically at risk in horses are the spines of the thoracic vertebrae as a result of saddle sores; the metapodials as a result of knocks from opposing hooves; and the feet where laminitis has caused rotation of the pedal bone through the sole of the foot.

Other infections specific to horses include poll evil and fistulous withers, both diseases caused by infection of the *bursae* or voids near the atlas or first thoracic vertebrae, respectively, leading to infection of the surrounding bones. Even with modern veterinary care these infections are very difficult to treat because the pus cannot drain out easily (Baker and Brothwell 1980). Another problem is caused by infection involving the joints. As with osteomyelitis, etc., this is usually the result of a wound and can cause infection and necrosis of joint cartilage as well as swelling of the joint capsule, all of which lead to new cartilage and bone formations during the repair response.

As discussed abov,e nutrition plays a large role in the growth of the skeleton but there are also issues that relate to nutrition in mature individuals. One pathological condition of skeletal development that is sometimes associated with malnutrition but can also be the result of infectious disease is the production of Harris lines. These are lines of very dense bone, detectable using X-rays, running parallel to the epiphyseal fusion line. They occur when growth is slowed down for a significant period of time by any of the biologically stressful situations mentioned above (Baker and Brothwell 1980). The periods of stunted growth could lead to the shortening of the bone if the growth has not ‘caught up’ when more ideal conditions resumed.

Whilst oral pathology is not a topic that requires detailed discussion here, it is included because it can impinge on growth and skeletal maintenance through its effect on feeding. For instance, if the oral pathology is of such severity (either short term or prolonged) that feeding cannot take place adequately through pain, then the nutritional requirements of the individual could suffer and consequently this could affect the growth and maintenance of the bones, leading to all the problems associated with malnutrition outlined in Section 2.4.3.

Osteoporosis is a condition that affects horses as well as humans, and occurs when a lack of calcium in the diet causes a drop in the blood calcium, triggering a release of parathyroid hormones. This releases calcium from the bones in an attempt to maintain blood calcium levels to preserve normal nervous and muscle function. In the horse, as calcium is removed from the cranial bones, the fibrous connective tissue content increases and the head increases in size and appears swollen, hence 'big head disease'. Whilst it is uncommon to see such severe cases of calcium deficiency that result in big head today, it does appear occasionally (Hintz 1996). It is believed that less severe calcium deficiency in the limb bones (i.e. rickets) may result in a predisposition to lameness (Hintz 1996), probably as a result of the poor mineralization of the bones, enlarged joints and crooked long bones (Duren 1996).

Mild osteoporosis may not be detected on archaeological sites because often it affects all the bones when all the animals were raised in the same way. Therefore it appears 'normal' for that site (Baker and Brothwell 1980). Also, lightweight bones would, very often, be attributed to taphonomic processes rather than osteoporosis. In terms of biometric analyses, big head might result in anomalous cranium measurements being taken if the disease was not severe enough for easy recognition; however, at that stage the measurements are unlikely to be affected to any great extent.

There is a group of conditions and diseases that are commonly known in the veterinary literature as developmental orthopaedic diseases (DODs). These are a group of diseases that affect an animal whilst it is growing, either involving abnormalities in endochondral ossification, in bone lengthening or metabolic changes within the bone (McIlwraith 1996). Some of these resolve naturally, others only with the aid of advanced modern surgical techniques. This last group may, therefore, be detected archaeologically.

An eample of a DOD is epiphysitis, which manifests as pain and swelling at the growth plate. In horses this usually occurs in yearlings and foals around the distal epiphyses of the radius or the metapodials. Some cases have associated osteochondrosis (see below) but most do not. It can be associated with a high plane of nutrition, which has caused the diaphyses to outgrow the epiphyses, therefore a diet restriction will allow the joints to 'catch up' by slowing down growth in general (Pilliner 1992). Limiting the exercise of the horse helps to relieve the symptoms (McIlwraith 1996). Many cases resolve themselves with time and generally cease when the affected epiphysis fuses (McIlwraith 1996). As this condition usually resolves when growth ceases, it would not be detectable archaeologically (Baker and Brothwell 1980). Epiphyseal fractures can occur through trauma to the area where the cartilage is being calcified (McIlwraith 1996) and can result in sections of the epiphysis becoming displaced. These can still be seen after the bone has fused, as the displacement of a section of the epiphysis will still be evident.

Osteochondrosis is a defect in the endochondral ossification of the bones that can lead to several different specific conditions such as osteochondritis dissecans (OCD) and subchondral cystic lesions (SCL) (McIlwraith 1996). Both these conditions are caused when a restriction in the blood supply occurs in the cartilage precursor of the epiphysis, an abnormally thick layer of cartilage forms and some of this then undergoes necrosis, so the cartilage can then become detached from the bone through subsequent stresses, causing inflammation and pain (OCD) or can leave pits in the surface of the bone (SCL) (Figure 2.11) (Pilliner 1992; McIlwraith 1996). A number of other factors can contribute to the formation of these lesions, such as biomechanical stress, genetic predisposition, fast growth rate and nutritional imbalance, and therefore a multifactorial aetiology is generally accepted (McIlwraith 1996). There can be associated osteoarthritic lesions caused by incorrect use of the limb due to lameness.

In foals bred to grow quickly, the high plane of nutrition fed to these youngsters can increase the risk of OCD occurring. Low copper levels in the diet (Pilliner 1992) and imbalances in growth hormones have also been found to be exacerbating factors. It is most often found on the surfaces of the distal femur, distal tibia, proximal astragalus, distal metapodials and shoulder joint (Pilliner 1992; McIlwraith 1996). OCD can be recognised in archaeological material as a depression in the underlying bone.

Subchondral cystic lesions (SCL) occur in any joint, but are particularly associated with the limb joints, and in horses most commonly occur on the distal femur, and less commonly on the proximal tibia, distal metapodials, both ends of the radius and on the phalanges. There is some controversy as to whether they are caused by a trauma that starts the process or not (McIlwraith 1996). SCL are only treatable with surgery, meaning that many horses in the past with this condition would probably have been lame. In archaeological material these would be seen as a much deeper depression than OCD, where the hole in the surface is much smaller than the underlying cavity.

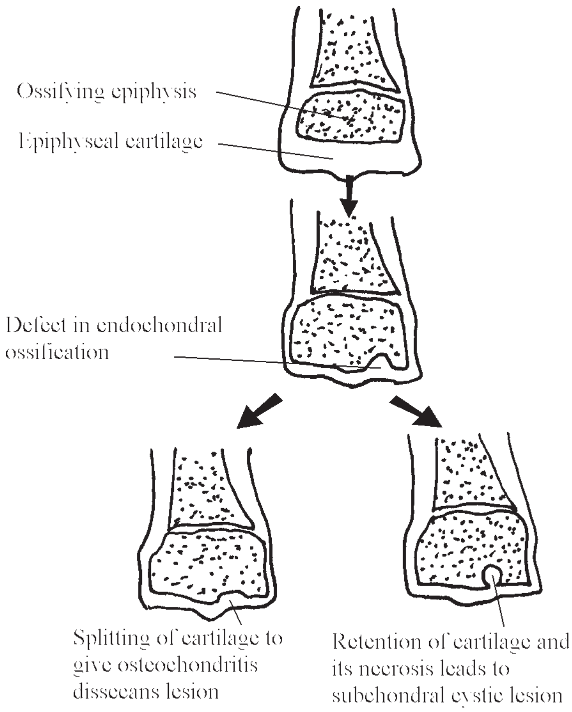

Figure 2.11. Formation of osteochondritis dissecans and subchondral cystic lesions (C.Johnstone after McIlwraith 1996).

Angular limb deformities (ALD) arise from uneven growth of the metaphysis or, less commonly, abnormalities of the cuboidal bones (carpals and tarsals). Abnormalities of the cuboidal bones are most often a problem with foetal development. After birth, the cuboid bones collapse because they are at an insufficient level of ossification to bear weight (McIlwraith 1996). It is unlikely that this condition would be found on archaeological material; however, it would be quite recognisable as it would not have been treated. ALD as a result of uneven growth (caused by unbalanced nutrition or hormones) of the metaphysis, most commonly involve the distal radius, metapodials and tibia. ALD can also be the result of crushing of the metaphysis by external trauma or excessive loading or exercise of the limb. This can lead to the early fusion of part of the epiphysis and therefore uneven growth (McIlwraith 1996).

Today, quite radical surgery is required to treat most cases of ALD, at sites other than the distal radius where it will usually correct itself (McIlwraith 1996). ALD would probably not have been treated in the past and could therefore be detectable in archaeological material, as bones with a lopsided appearance to the epiphyses. If the condition was not too severe then the animal would not be unduly affected in terms of movement. However associated osteoarthritis could well occur because of the uneven stress on the joints.

The next group of conditions are all associated with trauma and include fractures and dislocation as well as more minor incidents leading to the formation of haematomas. The latter are formed when a blood vessel under the periosteum is damaged and forms a blood clot between the surface of the bone and the periosteum, which then ossifies to form a smooth dense bony lump on the outer surface of the bone. Haematomas most usually form on bones where there is little surrounding soft tissue to protect the bone from knocks, such as the metapodials and skull. The lumps formed by haematoma should not be confused with the more regularly shaped dense bony nodules known as osteomata, which are benign bone tumours (Baker and Brothwell 1980). Dislocation of joints occurs in horses, but the muscle mass around most joints means that this is quite rare. The exception is dislocation of the hip joint, as evidenced by the formation of a false acetabulum on the pelvis to accommodate the femoral head on a few archaeological specimens (Baker and Brothwell 1980).

Fractures can occur in any place on the bone, including the epiphysis and the metaphysis. In growing bones, a fracture at the growth plate can lead to early fusion of the epiphysis as the repair process joins the two areas together, and hence the possibility of shortened bones. Sometimes the separation of the epiphysis can lead to a false joint between the epiphysis and metaphysis (Baker and Brothwell 1980). This is seen when a fracture of the femoral head occurs in horses (although the incidence of this is rare). Mid-shaft fractures of the long bones of horses are notoriously difficult to treat successfully, particularly in the upper limbs where the muscle mass is so great that straightening the fractured bone is almost impossible, particularly before anaesthetic and muscle relaxants were developed. Many horses sustaining a fracture would be put down immediately as their working lives would be over; perhaps this reflects the scarcity of identified fractures in the archaeological record. The metapodials are the most successfully treated, as evidenced by a well-healed fracture on a horse metatarsal from Skedemose (Sweden) (Baker and Brothwell 1980). This suggests that the animal must have been confined so that it could not move much until the fracture had healed, and that it was worth enough to the owner to allow it time to heal properly.

The last group of conditions to discuss are those that mostly affect mature and elderly individuals, namely degenerative conditions such as osteoarthritis, spavin, ringbone, navicular and spondylosis derformans. Although they can occur in younger animals as the result of a traumatic incident affecting the joints and soft tissues around them, these are mostly seen in older individuals as the result of general wear and tear on the joints. Osteoarthritis is caused by the degeneration of the joint cartilage leading to eburnation and grooving of the bone surfaces as well as bone growth around the margins of the joints known as exostoses. The presence of eburnation and grooving are the distinguishing features of osteoarthritis, compared with the following conditions (Baker and Brothwell 1980).

Spavin and ringbone are the names given to similar conditions affecting different joints of the limbs. Spavin affects the small tarsal bones and in extreme cases the proximal metatarsals as well. The joint capsule is affected and the formation of exostoses occurs between the tarsal bones, eventually leading to ankylosis of the joint. In ringbone, the inter-phalangeal joints are affected in the same manner, with high ringbone affecting the joint between the first and second phalanges and low ringbone the joint between the second and third phalanges. In both conditions the joint surface remains unaffected, so distinguishing them from osteoarthritis. Whilst the affected animals will be at least mildly lame, once the process of ankylosis is complete slow work can be resumed. Both conditions are thought to result from excessive stress on the joints concerned either through poor conformation not allowing the absorption of shock in the correct way, or as a result of too much fast work on hard surfaces (Baker and Brothwell 1980).

Navicular disease is peculiar to horses as far as can be determined. It is caused by the degeneration of the navicular bone, a sesamoid positioned at the posterior of the joint between the second and third phalanges. This disease should be easy to detect archaeologically because of the very characteristic way that the bone degenerates, but the navicular bone is not recovered very often, even from whole skeletons, perhaps due to poor familiarity with anatomy by the excavators or because those with navicular degeneration would be more vulnerable to taphonomic decay than healthy bone (Baker and Brothwell 1980). The condition causes severe and progressive lameness, but many animals would probably have been continued to be worked as there are no outward signs of the cause of the lameness.

As a slight deviation, another condition that causes foot lameness in horses is laminitis. This is a disease of the feet with a (still) unknown aetiology that causes inflammation of the lamellae holding the hoof horn to the third phalanx (pedal bone). If untreated it leads to the destruction of the lamellae, causing the pedal bone to drop downwards and even come through the sole of the hoof. In less advanced cases, the degeneration of the edges of the pedal bone is noted, where the blood supply has been disrupted and necrosis occurs. This bone degeneration is quite characteristic, but because of the bias against the preservation of third phalanges due to their porous nature, this disease is not often detected archaeologically despite its quite common occurrence in horse populations today. One exception to this comprises the four horse and two mule skeletons recovered from Künzing, Germany (von den Driesch and Cartajena 2001), which all exhibited chronic laminitis in at least two if not all four feet. It is surmised that these animals may have been put down because they were severely lame and hence unusable. However, it also suggests that they must have been used for a considerable length of time whilst they had laminitis for the hooves to have degenerated that far.

Ossification of ligaments and tendons occurs in horses, and is seen particularly in the ligamentum nuchae and the longissimus dorsi. This may be the result of using these animals for riding and traction, which places an abnormal stress on the structures. Extensive ossification can eventually lead to ankylosis of parts of the spine. Another condition that also causes this result is spondylosis deformans, where the destruction of the inter-vertebral discs and the eburnation of the vertebral bodies cause reactive exostoses to form around the margins, which eventually bridge the gaps between the vertebrae, leading to ankylosis. It might be expected that this kind of degeneration would be seen in the thoracic area as a result of bearing excessive weight in the saddle area, but it is mostly the lumbar region that appears to be affected (Baker and Brothwell 1980), perhaps in compensation for the weight further forward.

It is worth considering the consequences of the conditions outlined above. Many of the animals with these problems would have been lame to some degree, either temporarily or permanently, and yet from the advanced cases seen in the archaeological record these animals must have carried on being worked (Baker and Brothwell 1980). For some of the conditions, such as spavin and ringbone, the animal could still be used for slow work if it was rested until the bones had ankylosed, when the pain would have been less. It seems that when there was no obvious external cause for the lameness many owners may have just carried on using the animal regardless, either through ignorance of the discomfort the animal was in or because of a need to use the animal to earn a living.

Another aspect oto take into account is the indication that some animals, such as white horses, had a 'magico-religious significance and there may have been attempts to preserve the life of these at whatever costs' (Baker and Brothwell 1980). Wells (1972 quoted in Baker and Brothwell 1980) suggests that lame horses were specifically selected for burial with chieftains of the proto-Scythians of around 400 BC in Siberia, either just to get rid of unsound animals or to preserve the good ones. These gifts were supposed to represent things needed in the afterlife, so what the ghost chieftain thought of having a crippled horse with him in the afterlife is anyone's guess!

It has also been suggested that some Roman military stablemen kept severely lame animals alive in order to keep the rations allotted them so in order to feed other horses or sell the rations for a profit (Baker and Brothwell 1980). The disregard of equine welfare was not universal, as the many Roman veterinary texts give good advice on the diagnosis and treatment of conditions that cause lameness. For instance, Vegetius mentions both laminitis and navicular bone disease, and recommends various forms of treatment including paring down the foot to let out pus; further examples have been given in Section 1.3. However, it seems that where a profit or livelihood was at stake, the wellbeing of the animals may well have come second.

As stated at the beginning of this section, many of these diseases and pathological conditions would affect the measurements taken on archaeological bones, but the advanced cases should be recognised as pathological and subsequently not measured. It is hoped that the degree of inaccuracy resulting from the measurement of mild cases that are not recognised as abnormal is not likely to be outside the range of normal variation, and therefore should not unduly affect the results of this research. Individual cases that appeared to be outliers in any distribution wrere carefully checked with the original documentation to determine if pathology could be the cause.