BREAK A LEG: ANIMAL HEALTH AND WELFARE IN MEDIEVAL EMDEN, GERMANY

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Summary. The presented study investigates the pathologically changed animal bones from medieval Emden, Germany. Conditions are described, interpreted and compared with material from Ireland (a regional study including several historical sites), Germany (early medieval Hedeby and its successor Schleswig) and The Netherlands (Roman settlement Tiel-Passewaaij).
Keywords: Palaeopathology, spavin, traction, periodontal disease, animal bones, Emden.

SULAUŽYTA KOJA: GYVŪNŲ SVEIKATA IR GEROVĖ VIDURAMŽIŲ EMDENE (VOKIETIJA)

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Santrauka. Šiame darbe pristatomi viduramžių Emdene (Vokietija) iškastų gyvūnų patologiniai kaulų pokyčiai. Aprašomos kaulų patologijos, pateikiama jų interpretacija ir palyginimas su duomenimis iš Airijos (keletas istorinių gyvenviečių), Vokietijos (ankstyvųjų viduramžių Hedeby ir Šlezvingo) bei Nyderlandų (romėniškojo laikotarpio Tiel-Passewaaij) gyvenvietėse iškasta kauline medžiaga.
Raktažodžiai: paleopatologija, špatas, periodontitas, gyvūnų kaulai, Emdenas.

Introduction. This article is part of my forthcoming PhD-thesis which deals with the faunal remains from several excavations in the centre of the medieval town of Emden (Lower Saxony, Germany.). The aim of this thesis is to answer questions concerning the development of animal husbandry and the use of animal products in the medieval period. In this way, it is hoped to obtain a better understanding of the functions of a medieval town occupied by different groups of people and contrast this with the hinterland over a period of about 900 years (9^{th}-17^{th} century). Preliminary reports of this study have been previously published (Grimm 2005 & 2006). The final study will be published in the *Probleme der Küstenforschung* issued by the Niedersächsisches Institut für historische Küstenforschung, Wilhelmshaven (Germany).

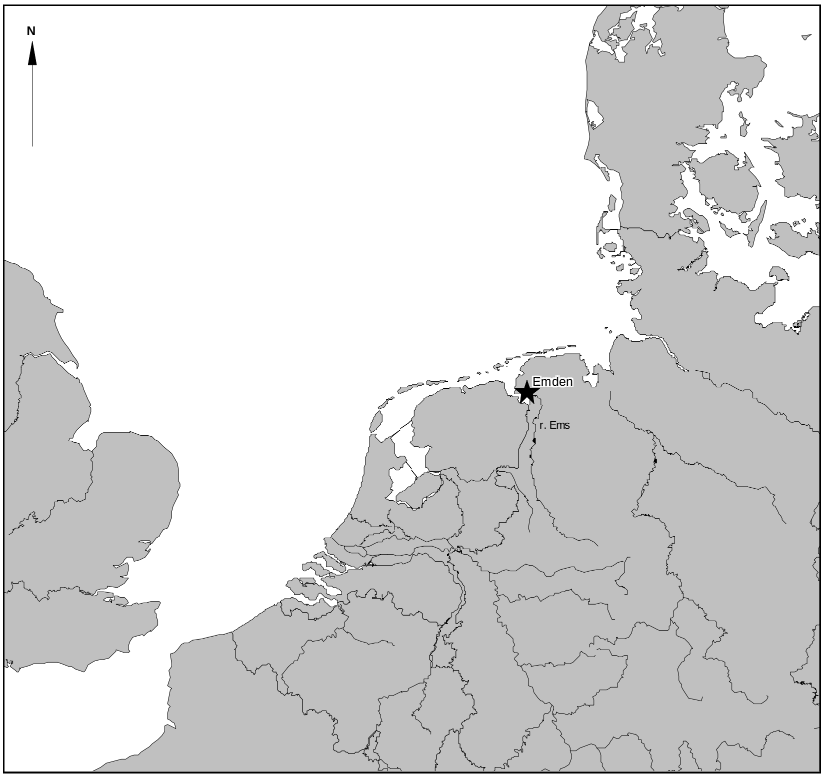

Figure 1. **Location of Emden and the river Ems**

When Emden was established in the 9th century, the town lay in-land as the Dollart (an inlet) had not yet been washed out by the Marcellus flood of AD 1362. Before the flood, the Dollart area was drained towards the river Ems by the rivers Aa and Tjamme. The surrounding marshland was filled with many peasant villages and several early economic centres. The villages Hatzum and Groothusen for instance, which developed in the 8th century, lay only about 11 km away from Emden. These early economic centres participated in a network of trading places connecting Scandinavia with the Mediterranean. The trading ships would navigate orientating on the coast line. The favourable situation of Emden at the mouth of the river Ems allowed it both maritime trade routes and a route inland via the river. Several small rivers and three roads, one of which lead to Münster, secured Emden's role as a trading place (Brandt, 1994).

The estuary of the Ems had become part of the Frankish empire around the time Emden was established as a regional market. Charlemagne granted the town to the earls of Westphalia. Frankish politics were beneficial to the trading network along the North Sea coast as it expanded in order to supply inland Westphalia (Hodges, 1999). Whereas the aforementioned Hatzum was ruled by a local chief, Emden was ruled directly by the king and his representative. This explains why Emden was allowed to mint and collect toll. Furthermore, the Vikings left Emden more or less alone. These favourable conditions contributed to Emden's success and soon the town dominated its surrounding trading places (Van Lengen, 1994).

The importance of Emden as a trading place declined at the beginning of the 16th century as the river changed its course in AD 1509; it no longer flowed directly in front of the town, but moved about 3.5 km away (Haarnagel, 1955). As a result, the port silted up. Together with the collapse of the Hanseatic League, the town started to decline. In AD 1744, after the death of the last remaining ruler of Eastern-Friesland, a descendant of the Cirksena family, the Prussian army occupied the kingdom of Eastern-Friesland. A new period of wealth began as Emden was the only port of Prussia on the North Sea and Friedrich I declared the town to be a duty free zone and cleared out its port and channel (De Graaf, 2001).

Material and Methods. The outbreaks of bluetongue[1] in the summer of 2006 as well as BSE and foot and mouth in cattle, sheep and pigs in recent years in north-west Europe have highlighted the impact of such endemics on both human and animal populations (Vann & Thomas, 2006). It is likely that similar outbreaks occurred in the animal populations of medieval Emden. Foremost, this would have had an impact on herd productivity with possibly part of the herd being temporarily or permanently unable to produce. Recently, there has also been worldwide concern for the development of the bird flu into a virus which can be transmitted between humans. Other high profile viruses which were (probably) transmitted between humans and animals and mutated include HIV, Ebola and SARS. Rabies is another virus that is mainly transmitted through bites (saliva) from infected animals. Bacterial infections which can be transmitted between animals and humans include tuberculosis and doubtless such zoonoses were important in the past.

People could have been further affected by health hazards caused by pus-forming bacteria when handling infected animals. Meat that was insufficiently heated to kill-off all the germs would have been a health hazard too (Teegen & Wussow, 2001) as well as milk and hides in the case of bovine tuberculosis (Mays, 2005). But illnesses are not the only causes for pathological changes to develop. Bacterial disease, sudden trauma injury, specific activity patterns, genetic defects and the wider environmental context (the substrates animals live on, amount of exercise, crowded versus open space, access to open air and diet) all play a role in the development of pathological changes (Niels Johannsen, University of Århus, pers. comm.). The study of animal health and welfare thus contributes to our understanding of how a particular species was used (economics: production), how they were kept (husbandry methods: transhumance, stalling, penning and stock density) and how they were treated (economics and cultural attitudes) (Thomas and Mainland, 2005).

Unlike in human palaeopathology, the analysis of animal palaeopathology has only recently moved away from the identification of gross morphological changes (the "interesting specimens approach"; Thomas & Mainland, 2005). This is probably due to the fact that the study of animal palaeopathology is hampered by the mostly disarticulated nature of the material. In the case of a grave, however, a whole human skeleton can be examined and the consequences of a particular condition can be studied throughout the skeleton which is key for achieving differential diagnosis, particularly when the skeletal responses to disease processes are relatively limited. Such links cannot be made with pathological changes found in butchery waste. Related to this are the impact taphonomic factors can have on the appearance of bone material making the recognition of pathological changes difficult. Secondly, most zooarchaeologists are not vets and are thus unfamiliar with the medical side of animal bone analysis. Thirdly, it is often difficult to pinpoint exactly what caused the observed changes in the bone as most conditions lack a single aetiology. This means that distinguishing between old age or over use is mostly not possible. Another major disadvantage is the lack of suitable comparative studies on modern material to establish the prevalence of a particular pathological change. The compilation of such data series is hampered by the fact that the current living conditions for animals are far more extreme compared to prehistoric times (bio industry or modern pets). Furthermore, farmstead animals are generally slaughtered at a (much) earlier age than they were in the past and thus had less time to develop the pathological changes seen in their ancestors.

The above problems have resulted in inconsistent recording, diagnosing and interpretation of pathological conditions seen in animal bone assemblages. The development of a standardised recording protocol for animal palaeopathology developed by Vann & Thomas (2006)

[1] http://www.blauwtong.info/

will hopefully enable detailed studies of regional or temporal trends in the future. Although this system was not yet developed when the pathological bones in the Emden assemblage were studied, its way of describing the bones was applied in retrospect. However, the calculation of accurate prevalence cannot be undertaken as the zonation system used at Emden does not allow for detailed observations; each bone was split into the proximal part, the shaft and the distal part, with a zone being scored when more than 50% of it was present. This system is cruder than the up to 12-zone system of Dobney & Reilly (1988) as recommended by Vann & Thomas (2006). Minimal numbers of prevalence, using the three-part zonation, were calculated in some instances. While the study of pathological changes encountered in the animal bone from Emden is limited by the same difficulties as described further above, some observations made can contribute to how a particular species' were used, kept or treated.

Discussion. In the Emden assemblage, only 156 fragments (0.08%) displayed clear pathological changes. This is undoubtedly below the actual number of pathologies present as the assemblage was not meticulously scanned for the less obvious manifestations like patches of new bone formation and enamel hypoplasia in teeth (see for instance: Dobney et al., 2006; Teegen, 2005a), etc. Furthermore, as Johannsen (2005) concludes, it is often difficult to pick up the 'early stages' of a pathology as the condition observed might well fall within the normal range. This problem particularly limits the use of slight morphological changes like some indications for draught exploitation (Bartosiewicz et al., 1997). It was felt that recording the obvious cases would be sufficient in this study to confirm patterns of animal use. In addition, although not many bones show pathological change, this does not mean that the animals of Emden were healthy. As the surrounding soft tissues and cartilage where the lesions possibly originated have disappeared, only the reaction of the bone to an illness can be analysed. Furthermore, disorders of a nutritional or hormonal kind can be better assessed by histological analysis than by gross examination (Siegel, 1976). Noteworthy, older animals have more "chances" to develop one or more diseases, which leave pathological traces on their bones, than young animals. Therefore, if domestic animal species were preferably killed at an early age (for instance the many lambs at Emden), the whole herd looks rather healthy (Siegel, 1976). In comparison, the Roman settlement of Tiel-Passewaaij had nearly 3% pathological bones (Groot, 2005). More in line with Emden is the 0.2% noted for the medieval bones from Hedeby-Harbour (Hüster Plogmann, 2006).

Of the 156 pathologically affected bones, 92 are cattle, 43 sheep/goat, 12 pig, 8 dog and 1 cat. Apart from the dog, which displays a higher proportion of pathological bones, these proportions resemble those of the overall bone assemblage. Murphy (2005) noted the same overrepresentation of pathological dog bones in her sample of historic Irish sites. In respect to the types of pathology encountered in the Emden assemblage, 34% are joint diseases, 27% are dental diseases and defects and 17% could be identified as trauma. The Irish historic sample studied by Murphy (2005) displayed a similar high proportion of joint disease related pathology, followed by trauma and dental diseases and defects. The relative low number of dental disease and defects noted by Murphy (2005) is interesting as it differs both from the results seen for Emden as well as from the high percentage reported by Siegel (1976) in her study of British sites.

Cattle

In cattle, the highest proportion of pathology is seen in the joints (58%), followed by trauma (24%) and dental related problems (8%). This corresponds well with the Irish data and underlines the idea that older cattle at the end of their useful live were brought to the meat market. Interestingly, spavin of the metacarpus was not seen in both the Emden and the Irish data and degenerative joint disease was almost absent in the shoulder joint. It seems that the activities undertaken by cattle during their working lives mainly put a strain on their hips and lower hind legs (Murphy, 2005). The importance of the use of cattle as draught animals must not be underestimated as it is estimated that even today c. 250 million cattle world wide are involved in traction (Starkey, 1991 cited in Johannsen, 2005). Cattle can be used for draught activities when about two years old. The training of a new animal is uncomplicated as it will learn quickly when harnessed together with an experienced older animal (Johannsen, 2005). As cattle were never meant to pull loads, the extra strain is likely to leave its mark on the bones. The study of pathological changes indicative of traction and the subsequent development of recording methodologies are summarized by Groot (2005) and do not need to be repeated here.

In the Emden cattle, degenerative joint disease associated with traction was seen in a scapula, five pelves, five femora, five calcanei, two tali, seven centrotarsi, two ossa tarsi II+III and 18 metatarsi. Three of the five pathologically changed pelves showed eburnation on the *pars lunata major* of the acetabulum. In one case this was accompanied by extra bone tissue bridging the *pars lunata major* with the *pars lunata minor*. Bridging without eburnation was also seen in one animal. Both phenomena might be the result of repeated over-rotation of the hip. Eburnation occurs when the cartilage that separates the bones in a joint wears away and bone rubs on bone. It is shown as a shiny patch on an articular surface. Corresponding to the eburnation seen on the acetabulum, five *caput femora* showed eburnation as well (prevalence 3.2%). The minimum prevalence seen in the medieval material from Schleswig-Schild is 2.3% (compare Hüster, 1990) and thus comparable to Emden. Groot (2005) also noted that in her sample of Roman settlement material eburnation was mainly seen in the hip joint and on the femoral head.

A special case of eburnation was seen in a 10^{th} century pelvis where the polishing was seen on the *Facies articularis* on the *Tuberositas iliaca* (joint with the sacrum). The latter may also be the result of the strain that traction puts on the back of the animal body, although according to Bartosiewicz et al. (1997) traction mainly adds additional load on the thoracic extremities and thus more pathology in the fore limbs. However, his study only included metapodials and phalanges as they were readily available from the slaughterhouses. In addition, new real-life observations by Bartosiewicz (pers. comm.) have shown that the initial jerk to start the load moving puts a heavy strain on the animal's rear. Eburnation was further seen on the articular surface of a scapula, an os carpi intermedium, two tali and three calcanei.

The classic pathological condition associated with traction and/or old age is spavin. It belongs to the category of *chronica deformans tarsi*; severe deformation of the tarsal bones (Daugnora & Thomas, 2005). Although it is associated with traction (Baker, 1984), spavin does occur naturally in horses due to age, weight or hereditary factors as evidenced by a find from the Late Neolithic site of Šventoji 23, Lithuania, where riding and traction had not been introduced into the area by this period (Daugnora & Thomas, 2005). Furthermore, the study of Romanian draught oxen by Bartosiewicz et al. (1997) showed that spavin was not exclusively related with the animals' use for traction. According to Von den Driesch (1975) spavin also occurs when animals have very little exercise. This holds true for animals that are always kept in a stable, a situation highly unlikely for Emden.

Spavin is a result of excessive compression of the joint. Over time, the cartilage between the upper and lower surfaces of the lower tarsalia and the metatarsal becomes compressed and erodes. The joint spaces then become smaller, and new bone growth occurs which eventually results in fusion (Baker, 1984). It is likely that complete fusion leads to stiffness (pers. comm. Wietske Prummel, University of Groningen).

In Emden, seven centrotarsi, two os tarsi II+III and 18 metatarsi (prevalence 12.8%) were affected by the condition. It seems that the initial stage comprises of osteophytes around the distal articular surface of the centrotarsal and the proximal surface of the metatarsus (see also: Bartosiewicz et al. 1997). The osteophytes create an articular extension. Six of the Emden metatarsals and four of the centrotarsals were found only to have osteophytes around their articular surfaces. The next stage seems to consist of pitting and grooving of the affected articular surfaces as pitting and grooving was only seen in combination with the osteophytes, it never occurred on its own. Three metatarsi and two centrotarsals were at this stage. The end result, an immobile joint where complete fusion between metatarsus and centrotarsal has taken place, was seen nine times. A metatarsus with articulating tarsals from the mid 9th-early 10th century shows that the os tarsi II+III fuses first with the centrotarsal before fusion with the metatarsus takes place. All bones show osteophytes and a pitted/grooved surface. As spavin is painful in the early stages, this animal may well have been slaughtered as a result. The fact that most bones fall either in the 'osteophytes stage' or the 'complete fusion stage' makes it likely that pitting/grooving of the articular surface is of short duration and happens immediately before complete fusion. Contrary, the material from Schleswig-Schild only contained two completely fused cases on a total of 88 (meta)-tarsals affected by spavin (Hüster, 1990).

Other pathological changes that might be associated with traction are the eburnation and osteophytes seen on the articular surfaces of a lumbar vertebra, nodules near the distal part of the first phalanx and the distal articular extension of the second phalanx. Furthermore, two cattle calcanei displayed sharp rims of bone on the medial *sulcus tendini*. The long muscle *Musculi flexor hallucis longi,* which originates from the lateral condyle of the tibia and ends at the first phalanx (Nickel et al., 2004), runs along the sulcus. Four cattle calcanei from 400-700 AD Eketorp Castle (Sweden) were found with the same condition and Telldahl (2005) states that it is likely that this morphological change is a result of overloading due to traction.

The questions that requires posing, however, is the extent to which the examples of degenerative joint disease relate to the use of cattle as draught animals, or to other factors, such as age, breed and weight? Groot (2005) argues that as the adult horse population of the Roman settlement at Tiel-Passewaaij does not display such a high instance of joint disease, adult cattle must have been used as draught animals. Unfortunately, the Emden assemblage only contains 46 horse bones compared to c 12.000 cattle bones. Of these 46 horse bones, none displayed pathological changes. However, if these conditions are mainly age-related, they should be present in the old sheep assemblage as well, even if one takes into account load-bearing differences of the skeleton in cattle and sheep. Upon examining the sheep assemblage, only three bones were identified with degenerative joint disease (see below); the majority of pathology encountered in sheep is of oral origin. Thus, the cases of degenerative joint disease seen in cattle cannot be solely contributed to old age although they are only seen in skeletally mature bones. The Emden cattle came from mixed sources with superfluous calves being slaughtered young, few animals being slaughtered between 7-14 and 19-24 months, quite a proportion slaughtered as subadults (prime meat yield) and nearly half of all animals reaching dental maturity (Figure 2). The subadult and dental mature animals could have been used as draught animals.

Breed characteristics like weight or foot conformation, however, cannot be so easily dismissed. In a way, pulling a load has the same effects on the body as being overweight. The cattle body is designed to bear most of the weight on its front legs and harnessing animals on the horns or around the withers adds extra strain to the front part of the body. Distinguishing between wear due to traction load or due to extra weight as a breed characteristic is thus impossible. However, there is little rational logic in having a cattle breed that puts on a lot of weight (meat) but suffers from a high instance of painful joints which potentially would make driving them to the market or the butcher "a pain". Furthermore, the animals are clearly not all slaughtered when they become lame with spavin. Instead, they are allowed rest so the joint can completely fuse and the lameness disappears, after which the animal can be used again.

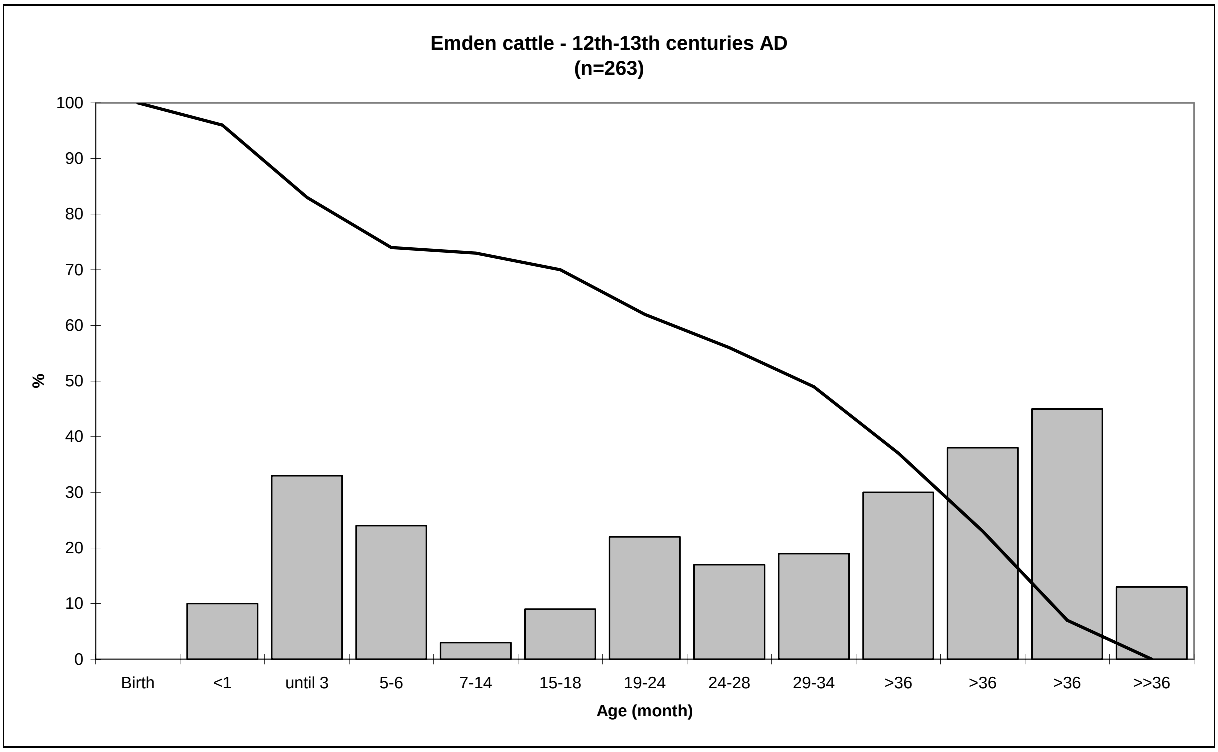

Figure 2. **Age profile diagram for Emden cattle in the 12th-13th centuries AD** (after Habermehl 1975)[2].

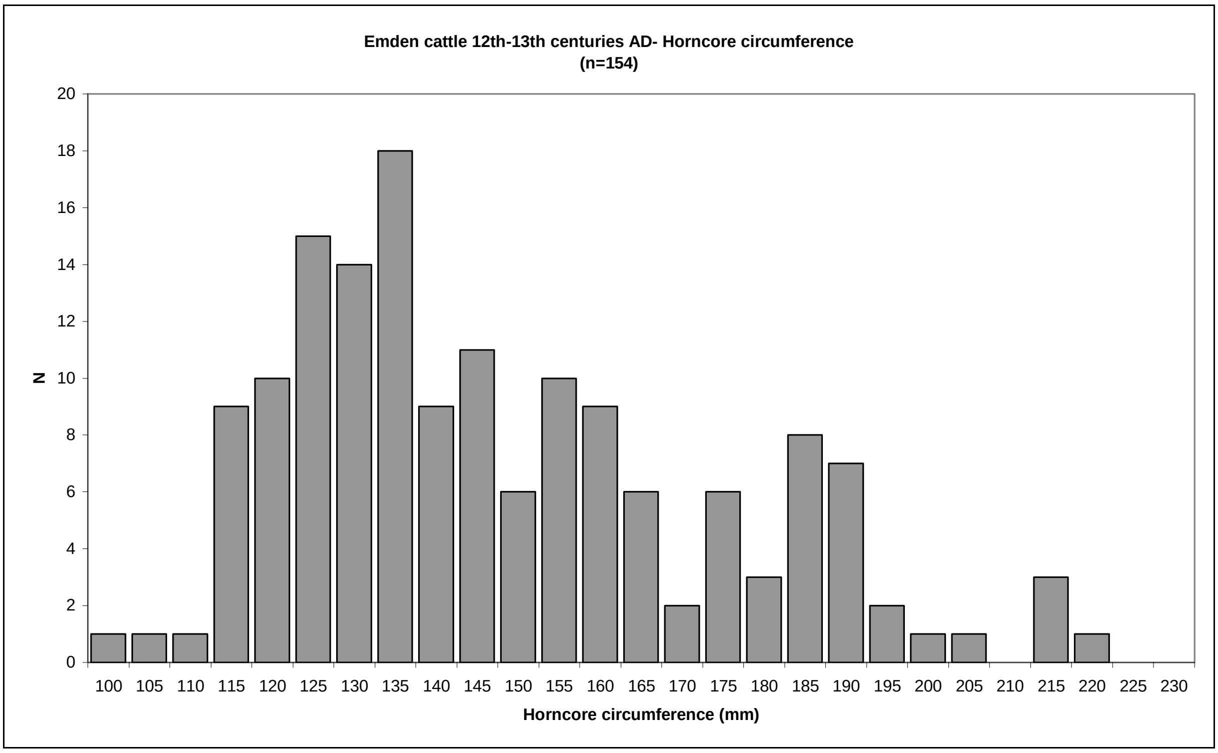

Figure 3. **Emden cattle horncore circumference** (basal) **in the 12th-13th centuries AD indicating bimodality probably relating to sexual dimorphism**

[2] The last three age groups are based on tooth wear and not on eruption; the last category probably comprises senile animals.

The influential study by Bartosiewicz et al. (1997) into the identification and recording of draught related pathology in cattle heavily relies on the principle of draught oxen. Hüster (1990) also links degenerative joint disease seen in the material from Schleswig-Schild (Germany) with "*Zugochsen bzw. älteren Rindern die Zugarbeit geleistet haben*". This is remarkable as she also states that sexing the horn cores showed that during the 11th and 12th century the sexes were balanced, whereas during the 13^{th} and 14^{th} century the ratio was close to 3 cows : 1 steer/oxen. She concludes that a shift in sex ratio must have taken place between the earlier and the later period. If this sex ratio difference is real, the number of cases of joint disease pathology should be higher in the earlier period as well. Unfortunately, Hüster's publication does not allow for such a comparison. Interestingly, a literature review in the same publication showed that the sex ratio in early medieval Hedeby and medieval Lübeck resembled the 3 cows : 1 steer/oxen (Hüster, 1990).

Groot's (2005) analysis of the cattle bones from the Roman settlement at Tiel-Passewaaij showed that some pelvis fragments with eburnation belonged to cows. The fact that adult cows dominate the assemblages from Emden (Figure 3), makes it likely that they were used for draught activities alongside the oxen. Unfortunately, the fragmented pelves from Emden (and Schleswig) were not sexed although recent research by Greenfield (2005) has shown that this is indeed possible. The use of cows instead of or alongside oxen makes sense as the ploughing of fields only takes place a couple of times a year before sowing. The rest of the year a cow can give milk, give birth to a calf or be used in front of a cart. Oxen can only be used for pulling carts, before being ultimately slaughtered for meat. Evidence for using sterile cows as draught animals can be found in Columella's *De re rustica* chapter 6 (Ahrens 1972). Modern pictorial evidence can be found in Bartociewicz et al. (1997, Fig. 6) and Groot (2005, Fig. 7).

Figure 4. **Cattle mandibler hinge displaying articular depression**

Three cattle mandibles showed various degrees of pitting of the temporo-mandibler joints. Since no osteophyte formation or eburnation was seen, it is probably not a form of degenerative joint disease (Figure 4). The lesions may instead represent osteochondritis dessicans (Richard Thomas pers. comm.). This is a "benign, noninflammatory condition of young adults characterized by the production of small, focal epiphyseal areas of necrosis on the convex surfaces of diathrodial joints resulting in partial or complete detachment of a segment of the subchondral bone and articular cartilage" (Aufderheide & Roderíguez-Martin, 1998).

Most trauma seen in the cattle assemblage comprised of healed/healing fractures and ossified haematomas of the ribs. Together with a healed fracture on the *processus spinosus* of a thoracic vertebra, they indicate the crowded housing of cattle. In such conditions the ribcage can be damaged by crushing between animals or buildings or as a result of butting. The occasional too forceful slap with a stick by the human caretaker or the stumbling and falling down of an animal cannot be ruled out either. Butting may also be responsible for the find of a horncore with a hollowed-out tip. The fragility of the bone substance made it difficult to determine if the cavity was the result of an inflammation due to trauma or had a taphonomic origin.

Figure 5. **Cattle metacarpus displaying possible healed fracture with secondary periosteal infection/inflammation.**

A 14^{th} century cattle metacarpus may display a healed greenstick fracture (Figure 5). Just above the distal articulation, the bone shows a large build-up of an irregular callus all around this part of the shaft. The distal articulation itself is not affected. The appearance of the bone reminds the author of a similar pathological condition seen in pig metapodials from several assemblages she has analysed. In one case the affected bones were radiographed which did reveal the fracture. Healed fractures in sheep metacarpals, a sheep and a goat metatarsal as well as roe deer metacarpals illustrated in Udrescu & Van Neer (2005) look all similar. Johansson's (1982) analysis of 86,524 cattle bones from Hedeby produced two metacarpals and two metatarsals with healed fractures. The metatarsus of Abb. 24/4 looks particularly similar to the specimen from Emden. Apparently, none of these bones were radiographed.

When a long bone breaks, contraction of the muscles will result in a shortening of the bone when realignment does not occur. Natural healing with consolidation in the anatomical axis and without shortening can occur when an adjacent bone is present that can act as a natural splint (Udrescu & Van Neer, 2005). Fractures of the metapodials in small livestock (sheep/goat and pig) may heal without much deviation from the anatomical axis even in the wild. In the absence of reference material from the wild, healed fractures in metapodials of large livestock are associated by Udrescu & Van Neer (2005) with human intervention. They further state that these fractures would have a better change of full recovery when the animal is young (i.e. greenstick fracture). We might thus have an example of Late Medieval veterinary practice where a fractured lower front leg of young cattle was cured by means of bandages and a splint. This would mean that the animal was kept in a stable to restrict its movements until the fracture was healed. The fact that the animal probably received care and attention instead of immediate slaughter shows that animals were valued beyond a ready source of meat.

The last group of pathological changes seen in the cattle bones from Emden comprises oral anomalies and defects. The Emden assemblage contained eight cases in which neither P2 nor the trace of an alveolus was detectable. Only in one additional case had the alveolus only partly remodelled. The minimal prevalence for an absent P2 in Emden's cattle mandible is 1.7%. Another, definite congenital anomaly is the absence of the *hypoconulid* in the lower third molar of cattle. With only two observations, this was not a characteristic of the Emden cattle population. Both oligodontia score much higher (14.6% and 13.7%) in the medieval cattle population from Schleswig-Schild (Hüster, 1990). Another possible congenital anomaly was encountered in the form of a round smooth rimmed extra foramen below the third premolar on the lingual side.

True dental pathology was seen in cattle in the form of periodontal disease. This is an inflammatory disease that begins as gingivitis. Gingivitis is caused by bacterial plaque that accumulates in the spaces between the gums and the teeth and in calculus (tartar) that forms on the teeth. These bacteria produce chemicals and toxins that cause inflammation of the gums around the teeth. The advanced inflammation causes deep pockets between the teeth and gums and loss of bone (resorption) around the teeth (periodontitis) with subsequent tooth loss. Severe ante mortem tooth loss can lead to starvation. The initial causes for the development of periodontal disease (and its progress), include the food consumed, the ingestion of minerals/particles from the substrate grazed and/or the oral environment of the animal (Davies, 2005). Four cattle mandibles (out of a possible 278) and one maxilla (out of 189) displayed the typical bone resorption of the alveolar margin indicative of periodontitis. No particular area was affected with porosity and resorption both seen around the roots of molars and premolars. Equally low numbers were seen for the Schleswig-Schild material (Hüster, 1990).

Sheep/goat

The 42 pathologies and anomalies seen in the sheep/goat assemblage include mainly dental related problems (n=38), three cases of degenerative joint disease and one trauma. A high amount of dental problems was also noted by Siegel (1976) in her account of pathologies and anomalies of British sites from the Neolithic to the medieval period and Groot (2005) in her account of the pathologies of Roman Tiel-Passewaaij. Conversely, Murphy (2005) noted mainly traumatic pathologies (fractures and ossified haematomas) in the Irish historic sample. Of the 38 dental related pathologies in the Emden sheep/goat assemblage, 26 (two in the maxilla) could be identified as periodontal disease (inflammation of the gum). In all cases resorption of the alveolar margin had led to the exposure of the roots of the teeth. It seems that in some cases the teeth had fallen out due to the loss of bone support. Inflammations were commonly seen around the first molar (n=19). This can be explained by the fact that the first molar is the first permanent tooth to erupt and wear. Consequently, free space between the first molar and the deciduous fourth premolar/permanent second molar make it easy for sharp parts of the fodder to penetrate the gum. This is further promoted by the fact that the mechanical stress is the highest on this part of the jaw. Bacteria that become active on these wounds can easily cause a paradontitis (Hüster Plogmann, 2006).

Other dental pathological changes seen on sheep/goat mandibles include an inflammation below the fourth premolar on the buccal side of the bone forming a possible abscess and a patch of periostal bone. Possible osteonecrosis in a sheep/goat mandible on the lingual side below P4, M1 and M2 resulting in an elongated broad groove with smooth rims was also noted. A third mandible had the possible rest of the deciduous fourth premolar wedged in between the permanent fourth premolar and the first molar. All three mandibles also exhibited periodontal disease. Two maxillae displayed dental defects. One involved the presence of a deciduous fourth premolar still rooted into the maxilla next to the permanent P4 (lingual side). The other specimen showed tooth rotation of the fourth premolar by approximately 20 degrees within the socket to form a malaligned tooth row. This probably let to abnormal erosion of the third premolar and the first molar. According to Davies (2005), prolonged deficiencies in the overall plane of nutrition can result in crowding, abnormal positioning or rotation of teeth.

The presence of an extra foramen beneath the premolar row on the buccal side of the mandible is a well known non-metrical trait in sheep. The condition is far less common in goats (Halstead et al., 2002) and was only occasionally noted (n=12) in the Emden material. The possible congenital absence of the second premolar was also occasionally noted (n=4).

Figure 6. **Sheep/goat tibia with affected distal articular.**

The non-dental related pathologies and anomalies consist of a mandible with the tip of its *processus coronoideus* sharp and irregularly shaped. It is uncertain if this is a true pathology or falls within the natural range of shapes for this part of the bone. Another mandible shows a pitted articular surface similar to a condition seen in some cattle mandibles (see above). A possible keeping-related pathology is seen on a tibia from the late 10th-early 11th century. The bone shows nodules around the distal articular surface resulting in an extension towards the medial side (Figure 6). Similar pathology on the distal humerus and the proximal radius are usually termed 'penning elbow' as they are thought to result from trauma inflicted by penning. A clear example of trauma is seen in a healed fractured rib from the mid 9th-early 10th century. Furthermore, a lumbal vertebra from the 9th century shows osteophytes around the distal articular surface resulting into lipping and restricted flexibility in the lower back.

A 12th century metatarsus might show a case of hormonal defect. The surface of this bone displays round shallow areas of approximately the same size, the margins of which are smooth. Although the surface does not look eroded, a taphonomic cause cannot be excluded.

Pig

The 12 pathologically changed pig bones from Emden include eight dental defects, two traumas and one joint disease. In addition, the partial fusion of the fibula with the tibia was seen in a subadult animal. The historic Irish pig sample was also dominated by dental defects and Murphy (2005, 18) attributes this to the omnivorous nature of the animals. However, the dental defects seen in the Emden material partly include the congenital absence of the P2 and an open space between the M2 and M3. In addition, a case of periodontal disease was seen in a maxilla and a possible case of enamel hypoplasia was seen on an incisor. Enamel hypoplasia is caused by stress during the developmental stage of the particular tooth.

A pig maxilla from the 14th-17th century displayed rotation of the second premolar by approximately 40 degrees within the socket to form a malaligned tooth row. Similar defects are described above for sheep/goat and might be due to prolonged nutritional deficiency or shortening of the snout due to domestication. A mandible from the 11th century showed the remains of a buccal abscess around M1 and M2. This possible inflammation of the *Sinus maxillaris* was clearly active at time of death as the surface shows porosity. A possible further case of pathology was seen in a 15th century mandible. This specimen displayed an irregular bone structure below the M3 on the buccal side.

Figure 7. **Young pig tibia displaying possible healed fracture.**

The two cases of trauma were seen on the Emden pig bones consisting of healed fractures. A left third metacarpus from the 9th century displays a healed fracture which might be the result of tethering the animal by the left front trotter. Another healed fracture was seen in a 13th century tibia where the fibula acted as a natural splint and fused with the bone (Figure 7). The animal was probably limping as the bone is bowed (healed under oblique angle). The small patch of woven bone indicates a (chronic) inflammation. A possible case of joint disease was seen in an ulna from the 14th century. The bone displays elongated vertical nodules on the articular surface with the radius (*Incisura radialis ulnae*). As the condition does not seem to have been active at time of death, it might just be an expression of natural variation.

Dog

Of the pathology encountered in the Emden dog assemblage, six involve the jaws and two are clear traumas. This dominance of dental related problems was also seen in the Irish historic sample (Murphy, 2005). Conversely, Groot (2005) recorded mainly traumas for the Roman dogs from Tiel-Passewaaij, while a palaeopathological study of the ribs and vertebrae of dogs from Hedeby, Schleswig and Starigard/Oldenburg undertaken by Teegen (2005) suggests that dogs in medieval German coastal towns were prone to abuse. Healed and healing fractures of the ribs and the spinous and transverse processes of the vertebrae are thought to be indicative of abuse, although biting by other dogs and kicking by livestock cannot be excluded. The dog bones from early medieval Hedeby Harbour exhibited a higher proportion of pathological changes than the material from its medieval successor Schleswig (or indeed Emden). Hüster Plogmann (2006) assumes therefore that dog care improved during the medieval period.

Possible breed related (congenital) dental anomalies are seen in a small brachymel dog skull from the 10th century. Both second molars are missing due to lack of space and the second premolar is missing on the right side. However, as the related right mandible clearly lost its first and second premolar ante mortem (alveoli have filled in), the latter might be the result of trauma (fighting with other dogs, blow to the jaw, etc.). A similar pathology was seen in a 14th-17th century maxilla where the fourth premolar was lost ante mortem, leaving a gap between the M1 and P3. As a possible result of senility, a mandible from the second half of the 13th century had lost most molars (alveoli filled). The remaining teeth were heavily worn and the premolars were crowded. The latter might be breed related.

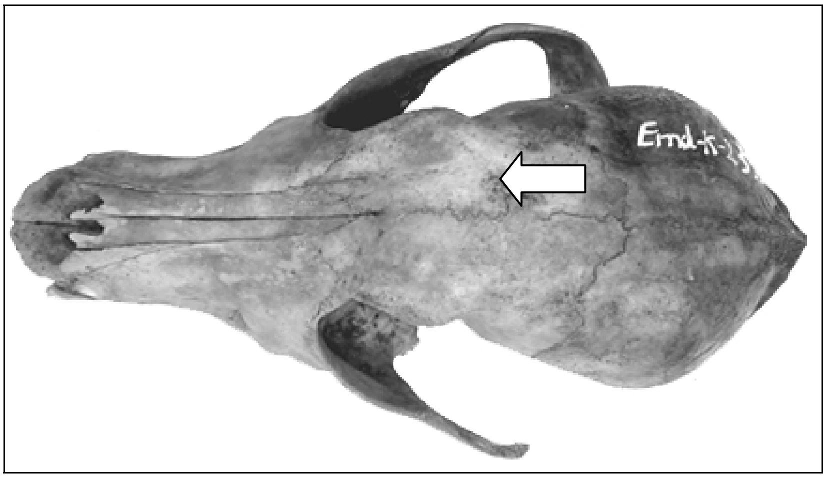

Figure 8. **Dog skull with possible healed trauma (arrow) resulting from a blow.**

Two dog mandibles show small sharp discrete nodules of bone, one beneath and just behind the third molar on the lingual side (base of bone) and one as an irregular extension on the *processus angularis*. Although the nodules were sharp, no new bone formation was seen on them, they might display natural shape variation therefore. In a 15th century dog, the pelvis and sacrum had fully fused. It is possible that this was the result of advanced age. A small semi-circular depression on the right frontal bordering on the sagittal suture, at the start of the brain skull was seen on a 13th century dog skull (Figure 8). The bone around and in the depression shows porosity and it is thus possible that the trauma was still healing at the time of death. It seems that this trauma is the result of a blow to the forehead with a blunt object.

Cat

A pair of cat mandibles from the 13th century showed a developmental rotation of the third and fourth premolar of approximately 25 degrees within the socket. This resulted in a misaligned tooth row in both mandibles. The same pathology was seen in four mandibles from medieval Schleswig. These anomalies are quite common in the modern cat population and it is thought that this is due to feeding cats processed food (Spahn 1986).

Conclusion

The study of the pathological bones in the medieval Emden animal bone assemblage has shown that similarities and differences exist between species, comparative sites and different chronological periods.

With respect to human-animal relationships it can be said that attitudes towards dogs probably differed from those towards cattle, sheep and pig. Dogs possibly show a higher instance of pathology which might indicate that they were prone to abuse (trauma) and/or a higher level of care (they survived long enough for the pathological changes to develop). Furthermore, the high instance of dental anomalies might be due to reduced snout length as a result of advancements in breeding. Active care towards cattle is indicated by the advanced stages of spavin which probably develop when an animal is allowed a period of rest. Veterinary interference might even be proposed in the case of a healed greenstick fracture in the metacarpus. The high instances of dental pathologies and anomalies in sheep/goat and pig might be the result of feeding of less suitable food stuffs or the absence of proper food during part of the year.

By paying more attention to pathological changes and by applying a more uniform recording system in the future, it is hoped that regional and chronological changes will become visible for horse, cattle, sheep/goat, pig, dog and cat. The presented study of the medieval Emden bone material hopes to contribute to this wider research agenda.

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