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DESCRIPTION, DIAGNOSIS AND THE USE OF PUBLISHED DATA IN ANIMAL PALAEOPATHOLOGY: A CASE STUDY USING FRACTURES

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Summary. In order to offer viable interpretations to archaeologists, experts in ancient animal disease are hard-pressed to diagnose pathological conditions whose osteomorphological symptoms are recognised during routine archaeozoological analysis. Since live bone tissue is known to have a limited repertoire of responses, it often reacts in similar ways to different pathogenic factors. Consequently, the usefulness of readily published diagnoses is understandably debated in the literature. However, there is a major body of such published finds, whose diagnoses should be critically integrated into the statistical/epidemiological evaluation of newly recovered palaeopathological finds. Based on the synthesis of 1294 of individual bone finds extracted from numerous publications spanning over half a century, an attempt is made in this paper to review the applicability of such data, demonstrating how their usefulness varies depending on the types of questions posed and the physiological nature of different pathological conditions. A special group of 261, mostly unambiguously identified, lesions resulting from traumatic injury, were analyzed in detail, in order to demonstrate differences in the taxonomic and anatomical distributions of symptoms in refuse bone material. In addition to skeletal morphology, live weight and animal behaviour, the prognosis of healing was established as an important factor in the manifestation of healed fractures in archaeozoological collections.
Key words: symptoms, bone fracture, aetiology, statistical analysis, databases.

APRAŠYMAS, DIAGNOZĖ IR PUBLIKACIJŲ NAUDOJIMAS GYVŪNŲ PALEOPATOLOGIJOJE

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Santrauka. Siekiant pateikti archeologams suprantamas interpretacijas, praeityje gyvenusių gyvūnų kaulų ligų specialistai verčiami diagnozuoti patologines būsenas, kurių osteomorfologiniai simptomai nustatomi atliekant įprastinį archeozoologinį tyrimą. Kadangi gyvo kaulinio audinio reakcijos galimybės yra ribotos, jis dažnai panašiai reaguoja į skirtingus patogeninius veiksnius. Taigi jau paskelbtų diagnozių vertė literatūroje dažnai yra abejotina. Dėl publikacijų gausos kritiškai įvertinti jų duomenys turi būti po įtraukti į naujų paleopatologijos radinių statistinę ir epidemiologinę duomenų bazę. Apibendrinę per pusę šimtmečio daugybėje publikacijų paskelbtų 1294 kaulų radinių, pabandėme įvertinti tokius duomenis ir parodyti, kaip jų vertė priklauso nuo keliamų klausimų pobūdžio bei skirtingų patologinių būklių fiziologijos. Išskirta ir detaliai išanalizuota 261 patologinis atvejis, kurių identifikacija kėlė mažiausiai abejonių. Taip norėta parodyti simptomų taksonominis ir anatominis pasiskirstymas. Be skeleto morfologijos, papildomai įvertintas gyvasis svoris ir gyvūno elgsena, gijimo prognozė – svarbūs faktoriai, veikiantys zooarcheologinėse kolekcijose nustatomų kaulų lūžimus.
Raktažodžiai: simptomai, kaulų lūžiai, etiologija, statistinė analizė, duomenų bazės.

Introduction. Animal palaeopathology, in its most frequently practiced form is empirical and inductive, although it is closely associated with processual archaeology. Owing to its origins in medical/veterinary science, however, palaeopathology is in need of testable hypotheses and relevant bodies of data. These, in turn, would offer a firm basis for archaeologically sound interpretations.

In principle, all palaeopathological studies ought to be based on the personal inspection, documentation and illustration of each specimen (O'Connor 2000: 100). Descriptions should always include detailed symptoms, rather than offering only "prefab" diagnoses, especially those borrowed from human palaeopathology, often in purely formal terms. Since, however, many common skeletal lesions in humans have morphological analogues in other mammals, there is a temptation to refer to parallels in human medicine on the basis of external osteomorphology. This line of reasoning may be misleading, except for the relatively rare cases when diagnosis directly reflects the possible aetiology of the disease. Fundamental differences in human and animal behaviour must also be kept in mind as well as the fact that osteological diagnoses will require perpetual scrutiny. Unfortunately, these simple and straightforward criteria are extremely difficult to meet even in modern veterinary medicine (Jubb *et al.* 1985: 79) owing to the analogous manifestations of different diseases in bone, a tissue possessing only a rather limited repertoire of usually slow reactions to a great variety of pathogenic effects.

This contradiction poses the challenge treated in this article, whose aim is to integrate a major body of heterogeneous data, largely published in the literature many years before the recently discussed need for scrutiny in recording strategies and analytical methods was recognized in animal palaeopathology.

Material and methods of classification. With the notable exception of a few specialized books and review articles, pathological cases in archaeozoology tend to be dispersed throughout the international literature, mostly within individual site reports. The relatively small number of curious but usually disarticulated fragments of diseased skeletal parts, however, would be difficult to evaluate disregarding the results of relevant previous research. Therefore, an attempt was made to outline a robust interpretational framework on the basis of the literature studied so far. It must be emphasized that this is an ongoing project and, in addition to its first application to a case study, this analysis a first attempt to appraise its strengths and weaknesses in its current state.

A literary source of prominent significance to this paper is the series of dissertations published by the Institute of Palaeoanatomy, Domestication Research and the History of Veterinary Medicine (München), mostly under the expert supervision of the late Prof. Joachim Boessneck (1925-1991). Many of these are reports produced by veterinary students, whose primary task was to demonstrate their identification skills in professional archaeozoological documentation rather than creating or contesting existing archaeological theories. These, as well as like-minded scholarly work across Europe and the Near East have been reviewed in an effort to gradually build up a database, to enable the evaluation of palaeopathological phenomena on a quantitative basis, facilitating reviews that, somewhat bombastically, may be considered „epidemiological" in nature.

As Baker (1978: 107) pointed out, the archaeozoological classification of animal disease should be based on its pathological aspects, which can provide some indication of the aetiology. Given the character of largely archival data available for this study, a complementary combination of archaeozoological and rough aetiological classification seemed most applicable. In its current state, this collection of literary data includes 1294 individual cases of pathological skeletal parts (the few articulated specimens counted as single entries) selected from 79 site reports and book chapters. This corresponds to a mean value of 16 bones with pathological lesions per faunal assemblage, a parameter of little interpretative value in itself. Each case in the database, however, is also characterized by the total NISP recorded for its assemblage of origin, as well as the percentage contribution of the species in question. The currently analyzed data originate from food refuse where such contextual information is more easily outlined; the study does not include special, often spectacular cases of animal burials, whose pathological analysis is facilitated by the availability of articulated skeletons for study (Bartosiewicz 2002a; see also Fabiš 2005), but often represent extremely special cases from an archaeological point of view. Naturally, the database also includes descriptions/diagnoses, the quality of which admittedly varies according to the skills of particular individuals and the details provided in individual reports. Currently, these data originate from 12 countries in Europe and the Near East, added to my own set of largely unpublished pathological specimens, although the organisation and expansion of the database is still in progress. Assemblages that contained bones with traumatic injury are summarized in the (Table 1) to this paper.

Table 1. **Abbreviations: n= number of pathological bones, NISP= number of identifiable specimens, BA= Bronze Age, IA= Iron Age**

Site name	Date/Period	NISP	n	Source
Altenburg-Rheinau	La Tène	N/A	5	(Karrer 1986: 71)
Alvastra	Middle Neolithic	2770	6	(During 1986: 112, Fig. 20)
Archsumburg auf Sylt	Roman	172	2	(Reichstein 1990: 280)
Arslantepe, Central Anatolia	Chalcolithic to Hittite	14672	90	(Bökönyi, unpublished)
Bad Kreuznach	Roman villa	7482	55	(Johansson 1987: 84)
Bad Salzulfen	AD 14-16th	560	1	(Schreiber 1989: 228-229, Abb. 1)
Bassam, NW Azerbaijan	2200-700BC	101703	1	(Krauß 1975: 205, Taf. 3/Abb. 7)
Bassam, NW Azerbaijan	7th c. BC	14568	1	(Krauß 1975: 110)
Bassam, NW Azerbaijan	AD 9-14th	6479	1	(Krauß 1975: 85)
Bentumersiel	Roman	4977	3	(Zawatka and Reichstein 1977: 110)
Breisach im Breisgau	Roman	N/A	1	(Schmidt-Pauly 1980: 97)
Breisach-Hochstetten	150-50 BC	6105	23	(Arbinger-Vogt 1978: 57)
Breisach-Münsterberg	La Tène	6997	11	(Arbinger-Vogt 1978: 134)
Burg Sponeck bei Jechtingen	Late Roman	25438	19	(Pfannhauser 1980: 105, Taf. 2/6)
Büyükkaya, Boğazköy-Hattuša	Chalcolithic- Early IA	935	8	(Driesch and Pöllath 2004: 31, Tab. 28)
Büyükkaya, Boğazköy-Hattuša	Chalcolithic-Hittite	148	3	(Driesch and Pöllath 2004: 31, Tab. 28)
Büyükkaya, Boğazköy-Hattuša	Early IA	7456	74	(Driesch and Pöllath 2004: 32, Tab. 28)
Büyükkaya, Boğazköy-Hattuša	Early IA - Middle IA	12387	18	(Driesch and Pöllath 2004: 32, Tab. 28)
Büyükkaya, Boğazköy-Hattuša	Hittite	2446	20	(Driesch and Pöllath 2004: 31, Tab. 28)

Büyükkaya, Boğazköy-Hattuša	Hittite-Early IA	5022	14	(Driesch and Pöllath 2004: 31, Tab. 28)
Büyükkaya, Boğazköy-Hattuša	Middle IA	4931	23	(Driesch and Pöllath 2004: 32, Tab. 28)
Cabezo Redondo, Villena, Alicante	2000-1000 BC, BA	33550	4	(Driesch and Boessneck 1969: Taf. 9/9)
Castellón Alto, Granada	1800-1500 BC, BA, El Argar	3652	4	(Milz 1986: 37)
Cerro de la Encina, Granada	1800-1500 BC, BA, El Argar	5528	23	(Friesch 1987: 54)
Cerro de la Encina, Granada	LBA	1619	5	(Friesch 1987: 39, Abb. 3)
Cerro de la Virgen, Granada	Copper Age/BA	51417	86	(Driesch 1972: 167)
Cerro del Real, Galera, Granada	BA	2308	1	(Boessneck 1969: 14)
Colonia Ulpia Traiana	AD 1-3rd	5268	25	(Schwarz 1989:117)
Dannenberg	AD 7-15th Medieval	87329	1	(Walcher 1978: 53)
Dannenberg	AD 9th Medieval	141	3	(Kocks 1978: 47)
Demircihüyük, Anatolia	2000-1500 BC	4167	2	(Rauh 1981: 87)
Demircihüyük, Anatolia	2700-2400 BC	41374	30	(Rauh 1981: 87)
Demircihüyük, Anatolia	mixed	19370	3	(Rauh 1981: 46)
Diconche	Late Neolithic	22639	48	(Bökönyi and Bartosiewicz 1999)
Dokkum, Friesland	AD 13th-14th	1146	5	(Van Gelder-Ottway 1979: 110, Fig. 1)
Dominsel Brandenburg/Havel	AD 10-12th, Slavic	19350	33	(Teichert 1988: 189, Taf. 18/6)
Egolzwil 2	Neolithic	n/a	1	(Hescheler and Rüeger 1942)
Feddersen Wierde	Germanic AD 3rd	50353	98	(Reichstein 1991: Taf. 29/1-6)
Griesstetten, Neumarkt	Late Neolithic	12697	6	(König 1993: Taf. 2/5)
Hämmerten, Kr. Stendal	Medieval	620	2	(Prilloff 1988: 63)
Hassek Höyük, Anatolia	Chalcolithic/EBA mix	4444	4	(Stahl 1989: 37)
Hassek Höyük, Anatolia	Chalcolithic	2972	5	(Stahl 1989: 37)
Hassek Höyük, Anatolia	3000-2000 BC, Early BA	12962	53	(Stahl 1989: 37)
Heilbronn-Neckargartach	Neolithic	3344	2	(Beyer 1970: Taf. 3)
Hekelingen III	Neolithic	1295	1	(Prummel 1987: 218)
Hildesheim-Bavenstedt	AD 3-5th	4747	13	(Missel 1987: 81)
Hitzacker	11-12th	15551	3	(Kocks 1978: Abb. 20)
Hitzacker	14th	8208	4	(Kocks 1978: Abb. 117)
Horum Höyük, Anatolia	Chalcolithic	4306	8	(Bartosiewicz in press)
Hundersingen an der Donau	6-5th BC, Celtic	21990	40	(Graf 1967: Taf. 3/4)
Hüfingen	Roman	77662	2	(Sauer-Neubert 1968: 33, Abb. 2a-b)
Hüfingen	Roman	87292	16	(Dannheimer 1964: Taf. 8/9)
Incoronata	8th-4th BC	1668	5	(Bökönyi in press)
Kalabak Tepe	7-5th BC	9872	4	(Zimmermann 1993: 34)
Kastell Vemania	AD 275-400	5709	14	(Piehler 1976: 101)
Kiel, Altstadt	AD 13-14th, Medieval	607	1	(Reichstein and Johansson 1981: 158)
Kongemosen	Mesolithic	N/A	3	(Noe-Nygaard 1989: 465, Fig. 7a-b)
Künzing-Quintana	Roman	4089	9	(Swegat 1976: Taf. 3/Abb. 6)
Lauriacum	AD 2nd	13311	11	(Baas 1966: 68)
Lauriacum	AD 2nd	13076	7	(Müller 1967: 142, Taf. 1/4)
Lidar Höyük, Anatolia	2000-1600 BC	190934	28	(Kussinger 1988: 82)
Lidar Höyük, Anatolia	3000-2000 BC	97111	1	(Kussinger 1988: 24)
Lidar Höyük, Anatolia	AD 4th-13th	486256	21	(Kussinger 1988: 24)
Lidar Höyük, Anatolia	4th BC-AD 3rd	131710	9	(Kussinger 1988: 121)
Lidar Höyük, Anatolia	6th-5th BC	97111	18	(Kussinger 1988: 25)
Lidar Höyük, Anatolia	1600-1200 BC, LBA	118684	1	(Kussinger 1988: 122)
LLantrithyd, South Glamorgan	Medieval	1525	4	(Noddle et al. 1977: 67)
Lübeck-Alfstrasse	Medieval	4529	4	(Rheingans and Reichstein 1991: 168)
Lübeck-Dr.Julius-Leber-Str. 58	Medieval	2156	1	(Pyrozok and Reichstein 1991: 199)
Manching	La Tène	118510	32	(Schneider 1958: 10)

Manching	La Tène	275830	1	(Petri 1961: 64, Abb. 11)
Manching	La Tène	N/A	4	(Pölloth 1959: Taf. 3/17a-b)
Manching	La Tène	118510	4	(Liepe 1958: 14)
Metaponto-Sanctuary	600–250 BC	1186	7	(Bökönyi in press)
Niederrealta Cazis	13-14th	8024	12	(Klumpp 1967: 45)
Pizzica-Pantanello	3rd BC, Archaic	398	3	(Bökönyi in press)
Pizzica-Pantanello	3000-2500 BC, Late Neolithic	692	7	(Bökönyi in press)
Pizzica-Pantanello kiln deposit	Roman	1598	5	(Bökönyi in press)
Riekofen	Late Neolithic	3310	1	(Busch 1985: 114, Abb. 8)
Sagogn	AD 10-14th, Medieval	25546	5	(Scholz 1972: 171, Taf. I/4)
Sagogn	Prehistoric	n/a	1	(Scholz 1972: 171, Taf. II/6a)
Sahr-i Sokhta, Sistan	Phase 3.5	515	3	(Bökönyi and Bartosiewicz 2000)
Sahr-i Sokhta, Sistan	Phase 5.5	1458	4	(Bökönyi and Bartosiewicz 2000)
Sahr-i Sokhta, Sistan	Phase 7.5	56	1	(Bökönyi and Bartosiewicz 2000)
Sahr-i Sokhta, Sistan	Phase 0.0	4813	12	(Bökönyi and Bartosiewicz 2000)
Sahr-i Sokhta, Sistan	Phase 5.0	3428	5	(Bökönyi and Bartosiewicz 2000)
Sahr-i Sokhta, Sistan	Phase 6.0	3070	12	(Bökönyi and Bartosiewicz 2000)
Sahr-i Sokhta, Sistan	Phase 7.0	594	2	(Bökönyi and Bartosiewicz 2000)
Sahr-i Sokhta, Sistan	Phase 8.0	596	2	(Bökönyi and Bartosiewicz 2000)
Schloss Nidau, Kt. Bern	AD 13-15th, Medieval	6192	5	(Nussbaumer and Lang 1990: 288)
Staatsforst Veldenstein	6-5th BC	4748	1	(Wessely 1975: 89, Taf. 11/25a, 26-27)
Takht-i Suleiman, Azerbaijan	AD 11-12th	1317	1	(Steber 1986: 72)
Takht-i Suleiman, Azerbaijan	AD 11-12th	6292	2	(Steber 1986: 23)
Takht-i Suleiman, Azerbaijan	AD 13-14th	5669	2	(Steber 1986: 23)
Takht-i Suleiman, Azerbaijan	4th BC-AD 10	1440	1	(Steber 1986: 23)
Talayot, S’Illot St. Lorenzo	Pre-Roman	10504	14	(Uerpmann 1970: 32)
Tel Dor, Area D2	IA	1866	5	(Bartosiewicz 2002b)
Tel Dor, Area H1	Roman	120	2	(Bartosiewicz 2002b)
Terrera de Reloj, Granada	El Argar culture, 1800-1500 BC	3307	4	(Milz 1986: 37, Abb. 13)
Unterregenbach	MA 11-12c	27115	3	(Kühnhold 1971: 36, Abb. 3a)
Valencia de la Concepción, Sevilla	Copper Age	28066	17	(Hain 1982: 94-95, Abb. 16a-b)
Velsen	AD 1st, Roman	3191	26	(Prummel 1987: 188)
Weinberg in Hitzacker	AD 12th, Medieval	10287	1	(Kocks 1978: 47)
Weinberg in Hitzacker	AD 7-15th, Medieval	87329	26	(Walcher 1978: 53)
Weinberg in Hitzacker	AD 9th, Medieval	141	1	(Kocks 1978: 47)
West Row Fen, Suffolk,	Early BA	31451	9	(Olsen 1994, 144)
Wiesenau	AD 7-8th Slavic	3079	2	(Teichert 1979: Abb. 2/7)
Wülfingen	AD 3-13th, Medieval	10776	1	(Hanschke 1970: 72, Fig. 13a)

A classical, purely empirical system for classifying palaeopathological phenomena in animals was proposed by Angela von den Driesch (1972: 167), in which three main categories of pathological modifications in animals were distinguished:

1/ Dental anomalies (supported by information on age and sometimes sex),

2/ Lesions caused by overworking and mistreatment (defined *a priori* on the basis of hypothesized aetiology),

3/ Traumatic lesions (identified most consistently on the basis of relatively clear symptoms).

This practical grouping, however, incorporates three different, intersecting paradigms (as indicated in parentheses), representing different dimensions of animal morbidity. Nevertheless, they are present in each case and should be considered as such. These different paradigms have recently been summarized as follows (Bartosiewicz 2002b: 322):

Ad 1/ *Taxonomic-anatomical:* teeth tend to be well preserved, easily identifiable animal remains. They make species identification, ageing and sometimes sexing possible. Evaluating anomalies against this background information is often more meaningful than the analysis of lesions in other parts of the skeleton, lacking in contextual detail concerning the individual’s biological status.

Ad 2/ *Aetiological-deductive:* osteological symptoms of the hypothesized forms of exploitation often coincide with those of aging. In addition, animals kept under harsh conditions tend to "age" faster. Distinguishing between these phenomena, therefore, is very difficult on the basis of disarticulated, individual bones. Moreover, overworking may also be manifested in the form of chronic and/or cumulative injury, thereby overlapping with the next dimension included in von den Driesch's classification, traumatic lesions.

Ad 3/ *Direct empirical:* with the exception of extremely complex cases, trauma is relatively easily identifiable on animal bones. Although the direct causes are rarely evident, the symptoms often look familiar and seem usually uncomplicated. The appearance of traumatic lesions, however, is not always easily explained by the form of animal exploitation (e.g. Uerpmann 1970: 84).

Since constructing this database is still under way and a broader basis will be needed to meaningfully discuss more complex pathological conditions, the group of traumatic lesions, representing the third, most direct empirical paradigm, was singled out for the purposes of this preliminary study. Although some traumatic injuries, especially compound fractures, may result in complex osteomorphological symptoms that make the precise identification of the lesion difficult, this is still the category in which diagnosis most clearly reflects the possible aetiology of the disease. Fractures and other forms of trauma are defined by symptoms that:

- once healed, tend to remain unambiguous,
- occur in wild and domestic animals alike,
- may result from accidents (caused by abiotic agents) as well as intraspecific or interspecific aggression, including human agency.

In addition to their identifiability, traumatic lesions are commonly recognized. Thirty-eight of the 79 reports included in the database discussed in this paper contained fractures and other traumatic injuries analyzed in this study.

Within the framework of this short paper it would have been impossible to make individual references to each source, however, all works used are listed in the bibliography (those without direct citations in the text are marked by an asterisk). Some geographical and diachronic interpretations of these data have already been discussed elsewhere (Bartosiewicz 2002, 2006), but fall beyond the scope of the present paper, which concentrates on a clearly defined class of traumatic lesions, fractures.

Taxonomic and anatomical distributions of skeletal trauma

In addition to the evident structural similarity but major functional differences between the skeleton of humans and larger mammals, central to traditional archaeozoological inquiry, osteological lesions are dependent on both the qualitative and quantitative traits of a species:

- *Qualitative differences* are represented by the specific skeletal morphology of animals, evident in the comparison of relatively distant taxonomic groups among mammals (e. g. the presence of horns or antlers, the degree of differentiation in extremity rays).
- *Quantitative differences* may usually be considered a matter of allometry, that is, a change in proportion of the parts of the skeleton related to changes in overall size. (e. g. limb fractures will have a better chance to heal in mammalian taxa, whose body weight is relatively small).

The complex relationship between the quantitative and qualitative aspects can be clearly illustrated by empirical data summarized by Baker and Brothwell (1980: 92, Table I). They listed the distribution of bone fractures across four mammalian orders (Carnivora, Perissodactyla, Artiodactyla, Proboscidea) and the species baboon.

This was a pioneering enterprise in spite of the nonchalance by which functionally very different animals such as rhinoceros and horse or deer and pig were pooled purely on the basis of Linnaean taxonomy. The main trend shown in their figures, however, largely corresponds to several decades of independent clinical statistics on domestic animals recorded at the University of Veterinary Sciences in Budapest (Tamás *ed.* 1987). The greatest differences between herbivores and carnivores as well as baboon is apparent in the relatively high frequency of healed radius and ulna fractures in carnivores. These may be interpreted in terms of (qualitative) morphological differences, since healing is facilitated by the complementary zygopodium bone, acting as a natural "splint" if only one of them is damaged. The quantitative aspect of this phenomenon is that the smaller body weight of carnivores exerts relatively small pressure on the injured limb. The healing of this trauma, however, is quite exceptional in large herbivores (Tamás *ed.* 1987: 299) whose radius is the only weight bearing bone in their forearm.

The same mechanism is manifested in auto- and metapodia. Among even-toed ungulates, the foot conformation of pig may be seen as a transition toward a more differentiated structure in carnivores. For example, a healed fracture in the 4th metacarpus of a domestic pig was reported from the site of Büyükkaya (Central Anatolia, Turkey; von den Driesch and Pöllath 2004: 32, Tab. 28). On the other hand, archaeological examples of healed metapodium fractures are a rare exception in horses, owing to the difficulties of curing injured individuals in this way (Udrescu and Van Neer 2005). The special care some broken-legged horses received is supported by iconographic evidence from the Middle Ages (von den Driesch 1989a). Nevertheless, rare archaeological examples of metacarpal fractures do occur. Two Iron Age examples include a simple fracture on a metacarpus that healed with a minor dislocation and minor shortening reported from the hill-fort of Stična in Slovenia (Bökönyi 1994: 203, Fig. 142). *Dislocatio ad axim* also caused major shortening of a horse metacarpus embedded in callus found at the Celtic settlement of Manching (von den Driesch 1989b: 651, Fig. 12). Similar healed fractures are virtually unknown in cattle metapodia, in spite of the fact that the numbers of their bones exceed those of horse by several orders of magnitude at archaeological sites. The prognosis of this trauma seems better in small ungulates of lesser body weight. A simple metacarpus fracture healed with minimal dislocation in a Copper Age sheep from Cerro de la Virgen, Granada (Spain; von den Driesch 1972: Taf. 9/32). Callus formation was limited to the bone's plantar surface.

In addition to variability in skeletal structures, functional differences attributable to specific behaviour must also be reckoned with. Fractures of the human forearm in archaeological assemblages can be interpreted as consequences of intraspecific, interpersonal violence (e.g. Salib 1967; Angel 1974; Ortner and Putschar 1981) within the context of bipedalism, as they are usually described as resulting from an individual's attempt to ward off blows directed at the head or upper trunk. Baculum fractures in carnivores represent another, more fitting example related to animal behaviour: the only way these bones may have been broken in powerful mammals such as cave bear (Tasnádi Kubacska 1955) or walrus (Capasso 1999, Bartosiewicz 2000) was during mating fights between males that failed to cease at the time of copulation. These species are, however, of marginal importance from a general, archaeozoological point of view.

Aside from such clear differences between skeletal trauma in mammalian orders, a high degree of intraspecific variability should also be considered with respect to the anatomical distribution of traumatic lesions. In humans this has been clearly demonstrated owing to the availability of large scale, clinical data sets. In their broad-based analysis of a dozen fractured bones from Neanderthals, Berger and Trinkaus (1995: Table 2), listed statistics of modern human populations, including a small group of rodeo riders. When trauma in baboons (Bramblett 1967) is compared with their data, it becomes even more clear that vigorous and sometimes aggressive physical activity represented by rodeo riders and to a lesser extent the small number of Neanderthals studied, is comparable to the distribution of bone fractures in these free living animals. Head injuries are less frequent in ordinary modern human populations, while their hands and legs seem to be relatively more exposed to injury. This trend is clearly apparent, in spite of the incomparably smaller size of sample of the three high risk groups vs. large scale, clinical statistics from modern urban contexts (Figure 1). These observations, often involving humans as well as special cases of rather exotic species and modern data can be further investigated using the database under construction. The archaeozoological significance of this body of information is that it is largely based on the remains of the most commonly exploited domesticates as well as the most widely hunted (usually large) game. The contribution of the latter, however, may be considered almost negligible to the palaeopathological database. This is not only because of the selective pressures of lame animals in the wild, but also reflects the fact, that in many post-Neolithic archaeological sites in Europe and the Near East an overwhelming predominance of domestic animals may be observed, providing a richer pool of potential pathological specimens. The anatomical distributions of traumatic lesions, which typically occur in the form of healed fractures, are summarized in Table 2.

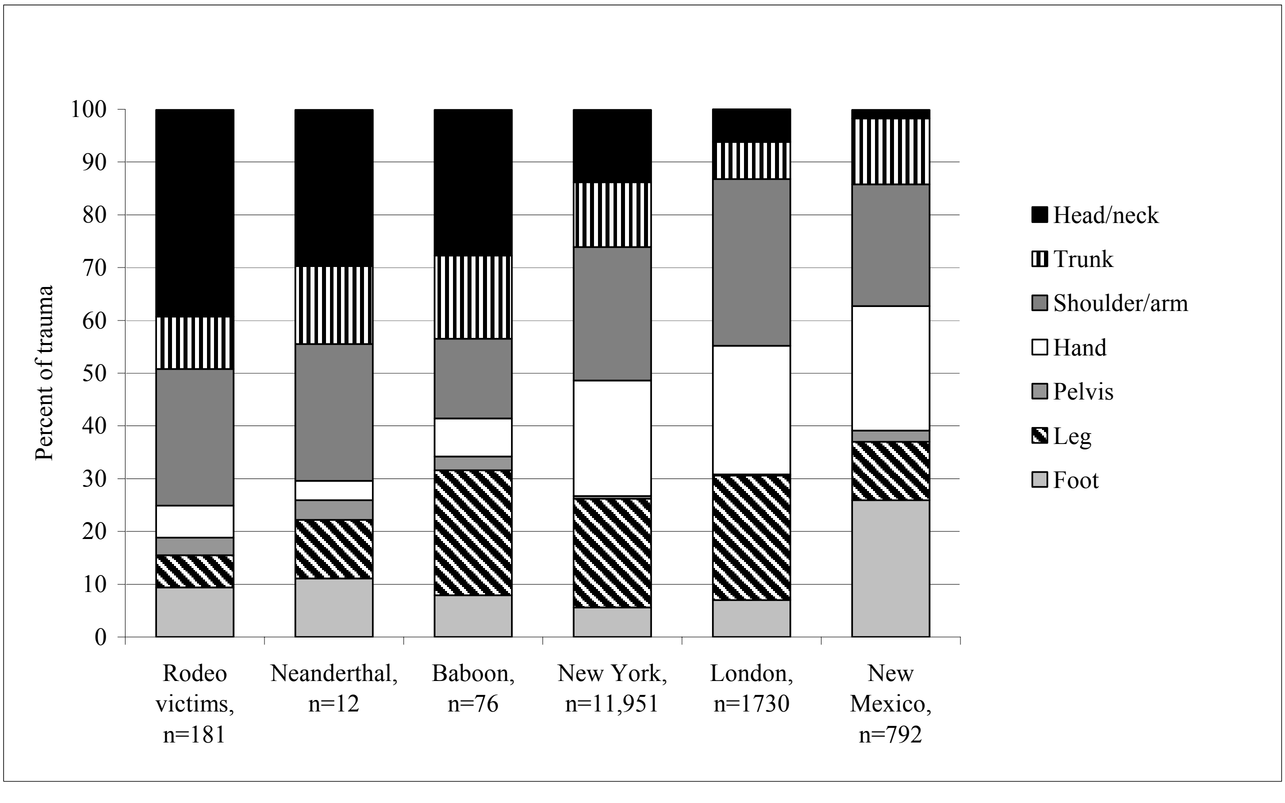

Figure 1. **Activity-related differences in the anatomical distribution of fractures in Hominids and baboon**

Table 2. **The anatomical distribution of bone fractures from archaeological sites in major groups of mammals**

	Equid	Large ruminant	Small ruminant	Pig	Carnivore	Total
Head	1	6	3	74	8	92
Vertebrae			2			2
Sternum		1				1
Ribs		34	15	7	7	63
Scapula		3		7	1	11
Humerus		1		2		3
Ulna			3	3	3	9
Radius			4		4	8
Pelvis		2	1	1		4
Femur				1	4	5
Tibia		2	11	17	2	32
Fibula				5		5
Calcaneum			2			2
Metapodium	3	9	8	2		22
Phalanges		2				2
Fracture total	4	60	49	119	29	261
(All lesions)	74	550	253	283	88	1248
Fracture %	5.4	10.9	19.4	42.0	33.0	20.9

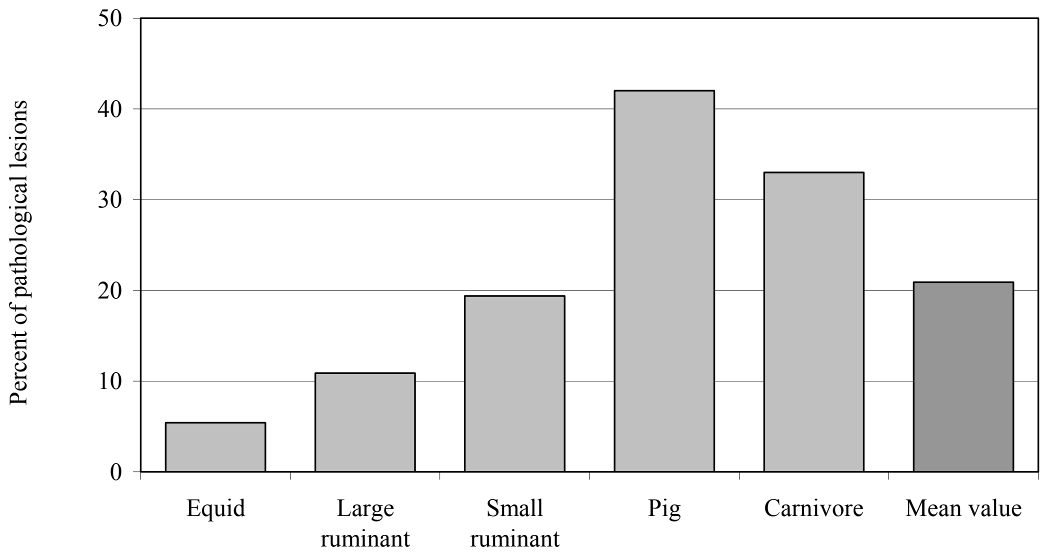

Figure 2. **Taxonomic differences in the contribution of fractures to 1294 pathological lesions**

Before analyzing the anatomical distribution of fractures in various animal groups, it is worth mentioning that the contribution of healed fractures to pathological lesions in general, differs markedly within this broadly defined taxonomic range. The percentage of traumatic lesions is shown in Figure 2. The small incidence in Equids is understandable in light of the aforementioned anatomy and special role of horses. These animals, exploited for their secondary products, tend to live to advanced ages, making the development of age-related chronic conditions (e. g. arthritis) proportionally more important. The opposite of this logic is shown by the outstanding frequency of healed fractures in pig. As prolific meat purpose animals, pigs tend to be slaughtered at a young age, before most pathological conditions (except fractures) would start affecting their skeletons. Moreover, broken bones are more likely to heal (i. e. be manifested) in young individuals, especially of relatively small live weight. The previously outlined importance of the animal's size is clearly shown by the twofold relative frequency of fractures in small ruminants (sheep and goat) in comparison with large ruminants (mostly cattle) of morphologically identical skeletal makeup. Naturally, the different forms of (secondary) exploitation of these animals may also play a role in creating this spectacular difference. The second highest incidence of healed fractures in carnivores (mostly dogs and some cat) is somewhat surprising, since the dominant species, dog, is often kept as a companion animal that should promote longevity, i. e. a higher proportion of chronic lesions rather than trauma. However, coexistence between dogs and humans was not always amiable as is shown by the presence of skull injuries (Tamás *ed.* 1987: 44).

In order to make the data listed in Table 2 testable in statistical terms, skeletal elements were grouped by gross categories, representing major body regions (Figure 3). The taxonomic/anatomical heterogeneity visually apparent in this graph was reconfirmed by calculating a Chi square test (Table 3).

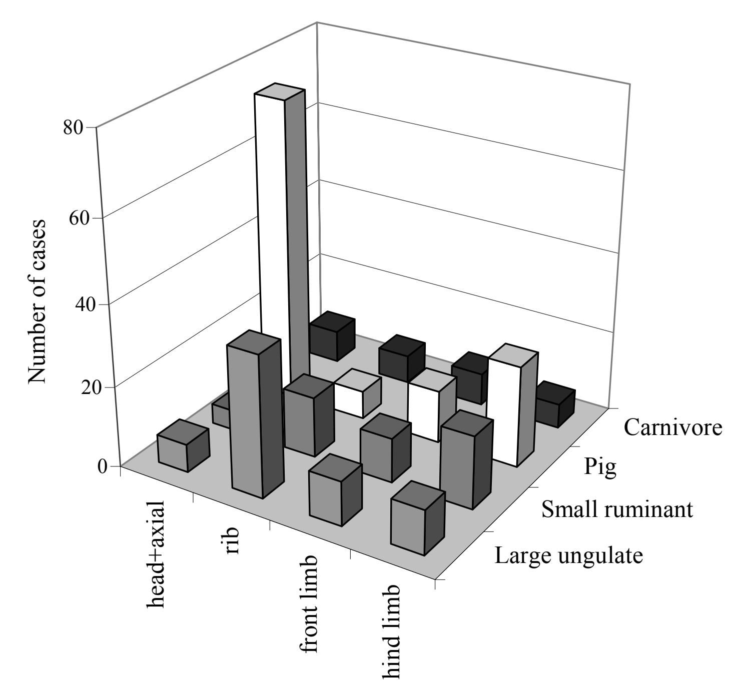

Figure 3. **The gross taxonomic and anatomical distribution of 261 bone fractures**

The resulting Chi-square = 92.1 value is highly significant in formal statistical terms ($P \leq 0.000$, degrees of freedom = 15), indicating that taxonomic differences seen in the anatomical distribution of bone fractures did not result by chance or through the vagaries of sampling.

Large ungulates

One of the major deviations from the norm, represented by expected values in Table 3, is healed rib fractures in the large ungulates. This must be, at least in part, a simple reflection of the aforementioned tendency of long bone fractures usually having fatal consequences in cattle and horse, where culling is often the preferred "treatment" owing to the poor prognosis of recovery. One may also presume that the risk of rib fractures is greater in large animals in the case of accidents, when the animal falls on its side and 300-800 kg of body weight may be involved in crushing a rib or two. Some rib fractures in working animals may also easily result from human abuse. Broken ribs, however, stand a much better chance of recovery, even among the largest of all studied animals: the archaeological representation of bone fractures is directly influenced by the chances of healing. For example, fractures of the pelvis (*fractura ossis coxae*) are among the most common form of skeletal trauma in modern livestock according to the decades long record kept at the University of Veterinary Sciences in Budapest (Tamás ed. 1987: 331). Archaeozoological reports reviewed for this article contained only two unambiguous cases of such trauma in cattle to date: a healed fracture or fissure from the Roman provincial settlement of Hüfingen (Germany; Dannheimer 1964: Taf. 8/9) and a *tuber coxae* with exostoses, possibly following the fracture of the ventral tuberculum from the Late Roman site of Burg Sponeck at Jechtingen (Pfannhauser 1980: 105, Taf. 2/5). The prognosis of hip bone fractures, especially in large ungulates, was probably rather grim in the distant past. In the absence of healing, osteological evidence of such accidents is largely absent from the archaeological record.

Table 3. **The distribution of bone fractures by body regions in mammals. Outstandingly high observed values are marked by boldface type. Expected values are calculated by multiplying the totals for each Animal x region and dividing the result with the grand total** (lower right corner of the table: e. g. pig rib E=64 x 119/261)

Animal	Large ungulates		Small ruminants		Pig		Carnivore		Total
Region	O	*E*	O	*E*	O	*E*	O	*E*	
head+axial	7	*22.8*	5	*17.7*	74	*43.0*	8	*10.5*	94
rib	35	*15.5*	15	*12.1*	7	*29.2*	7	*7.1*	64
front limb	11	*10.4*	11	*10.4*	13	*19.7*	8	*4.8*	43
hind limb	11	*14.3*	18	*14.3*	25	*27.0*	6	*6.6*	60
Total	64		49		119		29		261

Trauma on the skull and vertebrae of large ungulates, on the other hand, seem to be relatively rare. This phenomenon in archaeozoological samples is indirectly corroborated by the empirical observation that the relative contribution of vertebrae to all healed fractures in modern domesticates is only 5% (Silbersiepe and Berge 1958).

Small ruminants

In addition to the surprisingly low incidence of head injuries, sheep and goat (comparable to cattle in terms of skeletal morphology, but different in terms of size) are characterized by an unexpectedly high frequency of hind limb fractures. These are evidently less life threatening in the case of small ruminants whose live weight, on average, is only one tenth compared to that of cattle. Nevertheless, the front limbs still carry about two thirds of body weight in these animals, so their factures are probably less often given a chance to heal.

Pig

It seems that pig is a species prone to bone trauma, not only in comparison to other forms of skeletal lesions (as explained in relation to Figure 2), but in absolute terms as well. Anatomical and behavioural factors as well as specifics of meat exploitation may play a role in forming this marked tendency that seems even more dramatic given the usually short life span of these animals.

Most conspicuously, head injuries dominate not only among the bone fractures listed for pig in Table 2. This may be attributed to a great extent to pig ethology: animals often fight amongst themselves with their heads/tusks, causing pond-fractures, cracks and other non-fatal injuries that have a good opportunity to heal and thereby being manifested in the archaeological record. Another special feature of trauma in pigs seems to be the relative rarity of rib fractures that may have to do with the animal's shape (shorter legs, smaller weight), and perhaps also with its single-purpose meat exploitation: less direct contact with humans either reduced the risk of rib fracturing, or eventual blows were rather directed at the animals' head than in the case of working animals.

The high risk of damage in the hind leg of pigs is due to the frequency of a special form of injury: fractures in the distal third of the tibia and fibula. This trauma often heals with grave dislocation or complications. It was observed among the Roman Period pig bones from Tác–Gorsium (Bökönyi 1984: 111, Table 22). According to Benecke (1994: 166, Fig. 80) this type of injury occurs commonly at archaeological sites in Germany (e. g. Haithabu, Heuneburg, Hitzacker, Manching, Ralswiek) and is thought to be caused by tethering, tying a rope to one of the animals' hind legs. This seems a reasonable explanation, since pigs are difficult to get hold of: they have no horns to grab or a distinct neck to be safely collared.

Carnivores

Deviations from the expected values indicating homogeneity, are smallest in the case of carnivores, whose healed skeletal injuries seem to be evenly spread across major body regions. The example of carnivores (and previously discussed baboons) not only shows that species dependent activity means a predisposition to trauma more evenly manifested across the skeleton, but also illustrates that the probability of bone healing is higher in these relatively small animals of complex extremity structure. In addition, dogs are relatively unimportant from the viewpoint of meat exploitation. Zygopodium bones are of equal strength in the front limb of carnivores and that this probably contributes the high representation of healed fractures in this category. The importance of high differentiation between extremity rays is shown by the rarity of healed fractures in stylopodium bones (*fractura humeri et femoris*) in the archaeozoological literature, while they are relatively common in modern domestic animals (Tamás *ed.* 1987: 345). Among the archaeozoological specimens discussed in this paper, broken femora were recorded only in dogs and a cat.

Conclusions

Pathological lesions on excavated animal bones are rare and often poorly understood. Owing to the paucity of data, all possible cases available in the literature ought to be considered, in spite of their sometimes contradictory presentation. The quantity and quality of such information should be carefully weighed prior to use in ongoing analyses.

General

The database developed for the purposes of this study has shown that:

- sufficiently large samples are required for hypothesis testing,
- using gross categories of pathological lesions allows increasing sample sizes, however, this is at the expense of fine-grained diagnosis,
- quantitative analysis is an important aspect of palaeopathology, but does not substitute for the autopsy, i. e. eyewitness observation of individual bones.

Specific

At this point, bone fractures were deemed most reliable in terms of diagnosis and subjected to the detailed testing of hypotheses concerning their frequency distribution across taxonomic and anatomical categories. Even the relatively large palaeopathological database contained few broken bones. However, testing gross categories was successful in demonstrating that the frequency of healed fractures varies between major groups of animals, with significant differences between the anatomical parts in individual species.

Statistically significant trends show that the complex interplay between the following factors results in the variability observed in bone fractures:

- skeletal morphology (e. g. degree of differentiation in extremity rays),
- live weight (animal size has a direct bearing on the form and prognosis of bone fractures),
- behaviour (forms and intensity of activity, intraspecific aggression),
- form of exploitation (longevity and forms of abuse in domesticates).

This short analysis has shed light on the special importance played by the prognosis of recovery in the manifestation of [healed] fractures. Symptoms of *perimortem* trauma are usually difficult to identify among the sporadic food refuse (Bartosiewicz, in press). Grave bone fractures, however, often became fatal: they were neither tolerated by natural selection in the wild, nor supported by proper care among livestock. Therefore they represent an important but "invisible" entity in the palaeopathological literature. This is in contrast with the cultural phenomenon that sometimes animals must have been aided to survive, rather than being culled for practical or humane reasons. Such non-traumatic, chronic conditions often developed into extremely grave states, virtually unknown in modern veterinary practice (Bartosiewicz and Bartosiewicz 2002).

Perspectives of standardised recording

The importance of autopsy has been emphasized in the evaluation of fractures. As for systematic recording, the five categories of fracture listed by Baker and Brothwell (1980: 85) are perfect for the basic classification of this condition. The difficulty is that the archaeological manifestations of fracture types differ for a number of unrelated reasons. The five forms are listed below to express the decreasing probability of diagnosis:

1. Simple fracture (*fractura completa simplex*) is indicated by callus formation helping visual diagnosis. Dislocation makes identification even easier
2. Compound fracture (*fractura composita*) means that the fractured bone was exposed to the external surface of the body and became infected. Although is a brutally visible condition, its chronic form can be difficult to tell apart from other, non-traumatic inflammatory processes
3. Fissured and incomplete fractures (*fractura incompleta*) most commonly take the form of cracks in the skull, but as minor injuries they are sometimes difficult to recognize
4. Greenstick fractures (*fractura subperiostale*) may heal within the intact periosteum without marked traces
5. Comminuted fracture (*fractura comminutiva*) may be mistaken for *post mortem* fragmentation, as it shows "crushing" or multiple fragmentation. Animals would rarely recover from such accidents

As may be seen, a rather complex picture emerges even from this short, five item list that would be difficult to describe in a linear fashion. This would make the consistent scoring of bone fractures rather difficult. The lack of healing or the perfection thereof (esp. greenstick fracture) produce analogous results: they make certain fractures invisible in the archaeological record. Spectacular compound fractures, at the other extreme, must be carefully scrutinized for reliable diagnosis. The groups of simple and fissured fractures would stand the best chance of being unambigualusly identified in archaeological materials. In the future, however, standardised criteria would be worth drafting for the comparable description of such specimens across authors.

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