THE CONTRIBUTION OF ANIMAL DOMESTICATION TO THE SPREAD OF ZOONOSES: A CASE STUDY FROM THE SOUTHERN LEVANT

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Abstract - The advent of animal domestication was associated with marked changes in human-animal interactions, a process that had a significant impact on both parties. In animals these changes are expressed in features such as biogeography, morphometry and pathology. In humans they are reflected in changes in health, disease and demography as well as in social complexity. Current research on the origin and spread of emerging diseases, suggests that many infectious diseases common today originated in the process of animal domestication. The archaeological record of the Southern Levant (Lebanon, Southern Syria, Jordan, Israel and the Sinai Peninsula) provides an example of the possible role of animal domestication in spreading zoonoses.

Résumé - **La contribution de la domestication animale à la diffusion des zoonoses: le cas du Levant méridional.** Le début de la domestication animale a été associé à des changements remarquables des interactions homme-animal, ce qui eut d'importantes conséquences autant sur les hommes, que sur les animaux. En ce qui concerne les animaux, ces changements ont eu des conséquences de nature biogéographique, morphométrique et pathologique. En ce qui concerne l'homme, ils peuvent être corrélés à des changements de l'état de santé, de démographie et de complexité sociale. Des recherches en cours sur l'origine et la diffusion des maladies, suggèrent que plusieurs pathologies infectieuses aujourd'hui fréquentes trouvent leur origine dans le processus de la domestication animale. La documentation archéologique du Levant méridional (Liban, Syrie méridionale, Jordanie, Israël, Péninsule du Sinaï) fournit des exemples du possible rôle joué par la domestication animale dans la diffusion des zoonoses.

Key-words: Animal domestication, Zoonoses, Southern Levant.
Mots clés: Domestication animale, Zoonoses, Levant méridional.

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1. Introduction

The effect of the "Agricultural Revolution" on health status and nutrition has been discussed at great length in the scientific literature (Cockburn, 1971; Cohen & Armelagos, 1984; Cohen, 1989). As noted by Brothwell (1978), it constituted "a mixed blessing". On the one hand, it expanded the quantity and availability of food all year round. On the other hand, it was associated with marked changes, often deleterious, in the pattern of human disease. Several factors have been proposed to account for this shift in human health status. They include increased sedentism and population density, disease incidence and poorer nutrition reflected in variety and quality of foods consumed (Cohen & Armelagos, 1984; Cohen, 1989; Smith & Horwitz, 1998).

In this context, the role of animals as a source of infectious disease has been dealt with in the zoological and archaeological literature only in a cursory manner (Brothwell, 1978; Cohen, 1989; Siegel, 1976). However, the important role of animals as hosts and carriers of infectious diseases, at the present time (Twigg, 1980; Beran & Steele, 1994) suggests that changes in animal-human interactions resulting from the process of domestication, would have had a marked impact on the incidence and prevalence of infectious diseases in past communities. Evidence for this may be sought in the osteological remains of humans and their domesticates in archaeological contexts (Baker & Brothwell, 1980; Cockburn, 1971; Ortner & Putschar, 1985), as well as in ongoing research into the origins and evolution of pathogens (Greenblatt, 1998).

2. Zoonoses

There is considerable inter-specific variation in the susceptibility of animals to infectious organisms. In many cases, the animals act as a disease reservoir or intermediate host without succumbing to the disease themselves. Transmission to humans may be direct, for example, infection from saliva or blood from rabid dogs, droplets in the air from exhalation, sneezing or coughing or consumption of meat, blood or milk of a diseased animal (Cliff *et al.,* 1998). It may also be indirect from accidental ingestion of infectious organisms from fecally contaminated food or drink, or transmitted by bites of a variety of insect vectors such as ticks, mites lice and fleas (Beran & Steele, 1994). Examples of some arthropod borne diseases are Malaria and Dengue fever (mosquitoes), Lyme disease (ticks), typhus and plague (fleas). We propose that the short and intermittent contacts that took place between humans and their prey prior to domestication would have minimized opportunities for infection by any means other than direct consumption of diseased animals. Following domestication contacts between humans and animals increased with animals kept in close proximity to human settlements. In some cases, they shared the same dwelling space, greatly increasing chances for disease transmission, and attracting commensals that furnished yet another source of infection.

For humans, animal domestication was associated with:

i. Close, direct and prolonged contact between humans and animals including the keeping of pets, feeding and stabling of animals in or near human habitations. Milking and sheep- shearing would have increased the intensity and duration of such contact with animals and their by-products further facilitating the transmission of diseases.

ii. Increased sedentism, which is probably a pre-condition for domestication, would have increased the risk of infection from poor sanitation. The associated increase in population size, which characterizes the Neolithic period, would have exacerbated the situation and contributed to the increased level of infection in these populations.

iii. Use of animals for transport would have facilitated greater human movement and expand inter-group contact and trade ties. This would have increased the pool of people liable to infection.

iiii. The keeping of herd animals imposes constraints on settlement location-and especially on the proximity to water. This would have increased the likelihood of human infection from diseases such as malaria and schistosomiasis.

No systematic study has yet been carried out of pathologies associated with infectious diseases in faunal collections from different periods. However, many of the morphometric changes found in early herd animals (sheep, goat, cattle, and pig) appear to be at least partially due to nutritional impoverishment, over-crowding and loss of mobility following domestication (Zohary *et al.* ,1998). Diseased animals which would have died in the wild were perhaps able or even helped to survive in this new anthropogenic environment, which coupled with the proximity of other animals and humans would have helped to maintain and spread diseases. Consequently, even the earliest domesticate, the dog, may have been the source of many infectious diseases. Most of the diseases transmitted by dogs leave no specific trace on the bones or teeth. Some are fatal even today, others produce chronic ill health. A partial list includes rabies and possibly influenza; visceral leishmaniasis and amoebic diseases such as *Entamoeba hystolitica*, which causes cysts in the liver (Beran & Steele, 1994). Dogs also harbor ticks and fleas, while round worm, filarial worms and hydatid cysts are commonly transmitted to humans by accidental ingestion of fecally contaminated food or water.

Diseases commonly transmitted from herd animals include toxoplasmosis, brucellosis from sheep and goat milk, and tuberculosis from cattle. Both tuberculosis and brucellosis may cause specific bony lesions (Beran & Steele, 1994). Cattle and, pigs also serve, as the intermediate host of Cestodes, which cause tapeworms in humans when the flesh from infected animals, is eaten.

A variety of wild as well as domestic animals may be susceptible to tuberculosis (Beran & Steele, 1994). The disease may be air-borne, transmitted directly by saliva, milk or feces. Spores may also survive for a long time in the soil. Anthrax is caused by *Bacillus anthracis*, which can survive for decades by becoming dormant and only becomes re-activated when introduced into a conducive environment inside an animal host. Spores in dirt or dust infect cuts in the skin or mucosa. It affects a wide range of species, both domestic and wild and today occurs worldwide (Beran & Steele, 1994). Humans are relatively more resistant to anthrax than cattle but probably slightly less so than pigs and dogs.

3. A case study: the Southern Levant

3.1. - Animals

In the Levant, plant and animal domestication probably began in the Late Natufian period (10,500 bp) which witnessed the intensive exploitation of cereals and pulses, as well as the first appearance of the domestic dog. However, the full spectrum of animal domesticates is only completed by the end of the Iron Age (3,200 bp) (Tab. 1). Consequently, animal domestication in this region should be viewed as an ongoing process, which took place throughout much of the Holocene, rather than as single event.

Remains of the earliest domestic animal, the dog (*Canis familiaris*), have been identified from a number of Late Natufian (circa 10,500 bp) sites in the southern Levant. They are often found in association with human burials suggesting that they may have been perceived as high status animals (Tchernov & Valla, 1997). Human diet at this time was still based upon hunted and gathered fauna, as well as intensive collection of wild grasses and plants. This period also witnessed a marked increase in frequencies of commensal species such as the house mouse (*Mus musculus*), spiny mouse (*Acomys cahirinus*) and house sparrow (*Passer domesticus*) (Auffray *et al.*, 1988; Tchernov, 1984) a factor that may be correlated with increased human sedentism and food storage. Only by the late Pre-Pottery Neolithic B (PPNB) period (circa 8,500 bp), is there convincing evidence for the presence of domestic goats (*Capra hircus*). This is shown by marked changes in skeletal morphometry (high frequencies of twisted horncores and a notable reduction in body size), as well as in age and sex profiles goats (Legge, 1996; Garrard *et al.*, 1996).

These features all point to a significant change in patterns of animal management and one, which differs markedly to that, associated with hunting. At this time domestic sheep (*Ovis aries*) first appear in several sites in the southern Levant, all situated in, or adjacent to the Jordan Valley (Horwitz & Ducos, 1998). Sheep were probably introduced into this region from the north.

By the late PPNB, species richness and diversity in archaeological sites is reduced such that caprines are the main species exploited while other wild species such as gazelles, wild boar, aurochs, carnivores, birds and reptiles composed only a minor portion of the animal diet (Horwitz, 1996). Although there is no evidence for morphometric change in PPNB herd animals, many of them show a relatively high incidence of bone pathologies. Most common are exostoses (osteoarthritic deformities) primarily

Tab. 1- Number of diseases shared between domestic animals and humans (from: McNeill, 1976)

SPECIES	PERIOD WHEN DOMESTICATED	DATE DOMESTICATED (bp uncalibrated)	NUMBER OF SHARED DISEASES
Camel	Late Bronze Age	1,400	7
Poultry	Late Bronze Age II	1,400	26
Rats and mice*	Late Natufian	10,500	32
Horse	Chalcolithic	6,500	35
Pig	Pottery Neolithic	7,500	42
Sheep and goats	Late PPNB	8,500	46
Cattle	Pre-Pottery Neolithic C	8,100	50
Dogs	Late Natufian	10,500	65

* Commensals

found on goat phalanges probably the result of reduced mobility (Kohler-Rollefson, 1997; Goring-Morris *et al.,* 1995). They are also found in PPNB cattle from Jericho and 'Ain Ghazal (Clutton-Brock, 1979; Kohler-Rollefson, 1986). This contrasts to the situation for gazelle from the same sites which show no pathologies. One goat from the site of 'Ain Ghazal had a healed fracture, indicating that the animal was kept and cared for following this trauma. Another caprine from the same site exhibited resorption of bone in the limb extremities. This was interpreted as evidence for intentional tethering (Kohler-Rollefson, 1997). Although these pathologies are not associated with specific diseases, they do provide some indication for stress, presumably due to the conditions in which these early domestic animals were kept.

Morphometric change in herd animals attributed to domestication, is observed by the Pre-Pottery Neolithic C (circa 8,100 bp) (Ducos & Horwitz, 1998). By the Pottery Neolithic (7,500 bp) the faunal assemblages in the southern Levant are dominated by the main Near Eastern domestic animals: sheep, goats, cattle and pigs. Domestic donkeys first appear in the archaeozoological record of the southern Levant in this period. The donkey appears to have been introduced as a domesticate into this region from the south, possibly Egypt. Based on clay figurines from the Pottery Neolithic and the subsequent Chalcolithic period, they appear to have served primarily as pack animals (Ovadia, 1992). Domestic horses may have been present in the southern Levant by the Chalcolithic period (Grigson, 1993). However, their remains do not occur in any frequency prior to the Iron Age. It is accepted that horses were introduced as a domesticate into the southern Levant, either from Egypt or the Northern Levant. Camels too are clearly an introduced species. There is ambiguous data concerning their presence in the region in sites dating to the Middle Bronze Age, but by the Late Bronze Age they are definitely present. Poultry are found in substantial numbers by the Iron Age, but may have been introduced in the Late Bronze Age. Subsequent additions to the domestic fauna of the Southern Levant include the cat, domestic goose, pigeon and water buffalo introduced into this region more recently. The first evidence of milking dates to the Chalcolithic period, where ceramic vessels interpreted as milk churns, are common (Amiran, 1969). Cortical bone thickness in sheep and goats shows a marked decrease from Chalcolithic to the Early

Bronze Age, and remains low in later periods. This has been attributed to negative calcium balance resulting from the combined effects of poor nutrition and intensive milking. It indicates that only in the Early Bronze Age were herds of sheep and goat exploited on a large scale for their milk (Smith & Horwitz, 1984).

3.2. Humans

Chronic diseases are associated with impaired health and growth and frequently result in early death. Identification of a specific disease is however possible only if it produces a characteristic bony lesion that can be recognized in the teeth or bones.

Many diseases when first introduced into a human community are fatal, such that mortality may result rapidly before any signs are found in the skeletal record. Evidence for this may be indirect such as abandonment of sites or mass burials, where the age profile differs from that expected through natural mortality. The number of skeletal remains recovered from different periods is too small to attempt a detailed reconstruction of paleodemography. However, it does provide an opportunity to assess changes in life-span from an examination of the age at death. These data are calculated relative to the proportion of total adults identified, excluding children as their remains are poorly preserved or may have been buried outside of cemeteries. In the Natufian and Neolithic periods, only some 10% of adults appear to have survived beyond the age of 50 years. This frequency drops in the Chalcolithic period, where no individual appears to have survived to the age of 50. By the Middle Bronze Age (circa 3,750 bp) there is considerable amelioration with between 20-30% surviving to 50 or more years of age. In the Iron Age, the situation deteriorates slightly with less than 20% survival beyond the age of 50 years (Smith & Horwitz, 1998).

There is good evidence for increased environmental stress in Neolithic and Chalcolithic populations. This is shown by the high frequency of hypoplastic defects in the teeth, growth arrest lines in the long bones and osteoporosis in young adult females. In addition, cribra orbitalia and parietal pitting, show a concomitant increase (Smith *et al.*, 1984; Smith & Horwitz, 1998). These conditions are indicative of iron deficiency either through dietary deficiency, chronic anemia associated with intestinal infections or genetic factors affecting red blood cell formation (Stuart-Macadam & Kent, 1992). The first definite evidence of a specific disease transmitted by animals is found in the mid/late PPNB levels at the site of 'Ain Ghazal, where two individuals have been diagnosed as suffering from tuberculosis (El Najjar *et al.*, 1997). A number of other specimens from the late PPNB site of Basta and the PPNC of Ain Ghazal, also show bony changes that may be attributed to tuberculosis (Schultz & Scherer, 1991).

In the Chalcolithic period similar pathological symptoms associated with tuberculosis, but not pathognomic of the disease, have been identified from several sites including Shiqmim, Kissufim and Gilat (Zagerson & Smith, in press). The Early Bronze Age site of Bab edh-Dhra also shows evidence of tuberculosis (Ortner, 1979).

4. Discussion

The data presented here show that there is a clear association between animal and plant domestication and deterioration in health of humans and their herds. It seems that there was a significant deterioration in the health status of early Neolithic populations relative to that of the Natufian hunters and gatherers that preceded them. This trendbegins before the domestication of herd animals in the early phases of agriculture (Pre-Pottery Neolithic A period). However, it should be remembered that dogs were already domesticated by this time and are a major source of zoonoses. Deterioration in health is reflected in shortened life expectancy, the increased incidence of developmental defects and in osteoporosis and cribra orbitalia.

All these conditions may be associated with impoverished diet and/or failure to absorb foods (Smith *et al.*, 1984). We cannot at this stage assess the relative role played by changing diet versus disease on human health. However epidemiological studies of Third World populations have found that disease rather than diet is the main factor responsible for chronic ill-health (Cliff *et al.*, 1998). In the Near East the process of animal domestication occurred over several millennia. In terms of zoonoses, this would have meant the constant introduction of potentially new sources of disease as different animals were adopted into the anthropogenic domain. This scenario differs from that occurring in regions such as Western Europe, where domestic animals were introduced as a package within a relatively short period of time. We might then expect to find a less severe, but more prolonged impact on Near Eastern populations, where new diseases were introduced over a long period.

The earliest well documented evidence for early transference of disease from animals to humans is the presence of tuberculosis in humans in the late PPNB, populations the same time as a high frequency of foot pathologies is found in herd animals.

The pathology in herd animals provides convincing evidence for reduced mobility in these animals and probably reflects their deleterious living conditions. Such circumstances are known to be excellent breeding places for zoonoses such as bovine tuberculosis and provide a basis for the transmission of zoonoses in this period. The majority of domestic animals found in the Southern Levant (perhaps with the exception of the dog and goat) appear to have been introduced into the region as domesticates and did not undergo autochthonous domestication here. Consequently, it is expected that these animals would have brought with them new diseases for which neither the local wild fauna nor human communities would have developed any immunity. Although there is no direct for diseases introduced by these imported species, the continued deterioration in human health until the Middle Bronze Age period suggests that the introduction of new species was associated with new health challenges. The data are still incomplete, and we have highlighted here only one facet of the many changes in human society associated with animal domestication. A further indication of the contribution of human-animal contacts to the spread of diseases is shown by the correlation present between the time of domestication and the number of diseases shared with humans (Tab. 1). Thus, the species most recently domesticated, poultry and camels, share fewest diseases with humans while the earliest domestic animal, the dog, shows most (McNeil, 1976). These data plainly illustrate the direct connection between the process of animal domestication and the increase in infectious diseases in humans. They provide a starting point for integrating data from molecular biology with that derived from the archaeological record.

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