Was milk a “secondary product” in the Old World Neolithisation process? Its role in the domestication of cattle, sheep and goats

Jean-Denis VIGNE
CNRS, UMR 5197
Archéozoologie, histoire des sociétés humaines et des peuplements animaux
Muséum national d’Histoire naturelle
Bâtiments d’anatomie comparée, case postale 56
55 rue de Buffon, F-75005 Paris (France)
vigne@mnhn.fr

Daniel HELMER
CNRS, UMR 5133, Université Lyon 2
ArchéOrient
Maison de l’Orient et de la Méditerranée - Jean Pouilloux
Antenne de Jalès, F-07460 Berrias (France)
daniel.helmer@wanadoo.fr

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ABSTRACT
Beginning with a critical presentation of Sherratt’s model of the “secondary products” revolution, the authors review the most recent biochemical, isotopic and palaeogenetic evidence for early Neolithic milk exploitation in Europe. They suggest that there was a wide development of dairying which occurred much earlier than the “secondary products” revolution. Then they focus particularly on the osteoarchaeological evidence for the Near East and Mediterranean Europe. Using recent improvements in archaeozoological techniques for constructing and interpreting slaughtering age profiles which reflect animal management strategies, they analyse 36 sheep and goat and 17 cattle harvest profiles. They provide clear evidence for milk exploitation of sheep and goats as early as the first advances of the Neolithic in both regions, and strongly suggest that special management practices existed for cattle dairying. Altogether, these data indicate that dairy products were already part of the diet at the very beginning of the Neolithic process, and therefore should have played a role in the earliest Near Eastern domestication processes and in their spread to the Mediterranean basin. This evidence and its interpretation suggest that the Pre-Pottery (PPNB) Neolithic villagers were able to develop special technical innovations for the exploitation of early domestic animals as early as the mid 9th millennium BC, when they were still

"stock-keeping hunter-cultivators" rather than true farmers. This leads the authors to argue against the image of the last hunters having a low level of technical skills for animal management. Although still partly valid, the "secondary products" revolution hypothesis should be thoroughly revised. The terms "primary products" and "secondary products" should themselves be questioned: the authors propose to replace them with "final products" and "ante mortem (life time) products", respectively.

KEY WORDS
Neolithic,
milk exploitation,
dairying,
"secondary products",
slaughtering profiles,
Near East,
Mediterranean Europe,
PPNB.

RÉSUMÉ

L'exploitation du lait a-t-elle valeur de « production secondaire » dans la néolithisation de l'Europe ? Son rôle dans la domestication des bovins, des moutons et des chèvres.

En partant d'une présentation critique du modèle de la révolution des « productions secondaires » de Sherratt, les auteurs résument les récentes preuves biochimiques, isotopiques et paléogénétiques de l'exploitation néolithique du lait en Europe. Elles suggèrent que l'exploitation laitière s'est développée bien avant la révolution des « productions secondaires ». Dans un second temps, ils concentrent leur propos sur les indices ostéoarchéologiques au Proche-Orient et en Europe méditerranéenne. En s'appuyant sur les récentes améliorations des techniques archéozoologiques de construction et d'interprétation des profils d'abattage qui traduisent les stratégies de gestion des animaux, ils analysent 36 de ces profils pour les moutons ou chèvres (caprinés) et 17 pour les bovins. Ils mettent en évidence l'exploitation laitière des caprinés dès les tout premiers stades du Néolithique dans les deux régions concernées, et suggèrent fortement l'utilisation de pratiques de gestion adaptées à l'exploitation laitière des vaches. L'ensemble de ces observations indique que les produits laitiers faisaient déjà partie de l'alimentation au début de la néolithisation, et qu'ils doivent donc avoir joué un rôle dans la domestication des animaux au Proche-Orient et dans la diffusion de leurs descendants dans le bassin Méditerranéen. Ces observations et interprétations suggèrent que les villageois du complexe culturel nommé Neolithique Precéramique B (PPNB) étaient en mesure de développer des innovations techniques adaptées à l'exploitation des premiers animaux domestiques dès le milieu du 9^{e} millénaire, alors qu'il s'agissait encore de « chasseurs-agriculteurs élevant » plutôt que de véritables agriculteurs-éleveurs. Cela incite les auteurs à plaider contre l'image de derniers chasseurs à faibles capacités techniques dans le domaine de la gestion des animaux. Bien que toujours partiellement recevable, l'hypothèse d'une révolution des « productions secondaires » doit donc être profondément révisée. Les termes de « production primaire » et « secondaire » doivent eux-mêmes être remis en question : les auteurs proposent de leur substituer, respectivement, ceux de « production finale » et « du vivant ».

MOTS CLÉS
Néolithique,
exploitation laitière,
« productions secondaires »,
profils d'âge d'abattage,
Proche-Orient,
Europe méditerranéenne,
PPNB.

RESUMEN

¿Fue la leche un « producto secundario » en el proceso de neolitización del Viejo Mundo ? Su papel en la domesticación de bovinos, ovejas y cabras.

Comenzando con una presentación crítica del modelo de Sherratt sobre la revolución de los « productos secundarios », los autores revisan la evidencia bioquímica, isotópica y paleogenética más reciente para la explotación de la leche en el Neolítico temprano de Europa. Ellos sugieren que había un amplio desarrollo de la explotación de leche mucho tiempo antes que la revolución de los « productos secundarios ». Ellos se enfocan particularmente en la evidencia osteoarqueológica del Cercano Oriente y Europa mediterránea. Utilizando mejoramientos recientes en las técnicas arqueozoológicas para construir e interpretar perfiles de edad y matanza selectiva que reflejan las estrategias de manejo animal, analizan 32 perfiles de mortalidad de ovejas y cabras y 17 de bovinos. Ellos proveen claras evidencias que señalan la explotación de leche en ovejas y cabras tan temprano como los primeros avances del Neolítico en ambas regiones, y sugieren fuertemente que existieron prácticas de manejo especiales para ordeñar el ganado vacuno. En conjunto, estos datos indican que los productos lecheros ya eran parte de la dieta al comienzo mismo del proceso Neolítico y, de esta manera, podrían haber jugado un papel en los procesos de domesticación más tempranos del Cercano Oriente y su dispersión en la cuenca del Mediterráneo. Esta evidencia y su interpretación sugiere que los aldeanos neolíticos pre-cerámicos (PPNB) fueron capaces de desarrollar innovaciones técnicas especiales para la explotación de los primeros animales domésticos tan tempranamente como la mitad del 9[e] milenio AC, cuando ellos eran todavía « cazadores poseedores de ganado-cultivadores » más que verdaderos granjeros. Esto permite discutir a los autores contra la imagen del bajo nivel de habilidades técnicas de los últimos cazadores para el manejo animal. Aunque aún siendo parcialmente válida, la hipótesis de la revolución de los « productos secundarios » debería ser revisada cuidadosamente. Los términos « productos primarios » y « productos secundarios » deberían ser ellos mismos cuestionados : los autores proponen su reemplazo respectivamente por « productos finales » y « productos ante mortem (en vida) ».

PALABRAS CLAVE
Neolítico,
explotación de leche,
lechería,
“productos secundarios”,
perfiles de matanza selectiva,
Cercano Oriente,
Europa Mediterránea,
PPNB.

INTRODUCTION

Every scientist who deals with Old World Neolithic archaeology knows the “secondary products revolution” theory, advanced by the late Andrew Sherratt in 1981 and 1983. This theory proposed that dairying, wool and the use of animal strength for ploughing and carting (early horse domestication) originated as technical innovations in relation to meat production, during the 4th millennium in the Near East and during the 3rd millennium in Europe, *i.e.* at the very end of the Neolithic, four to two millennia after the emergence of animal domestication. It would have led to profound transformations in landscape and economy in these late Neolithic/Chalcolithic societies. This theory was based on both a classification of the animal products and a series of arguments.

The animal products have been classified in two categories, which were mentioned without any precise definition by Sherratt (1981: 261), then defined by Greenfield (1998, 2005): primary products, which can be extracted only upon the death of the animal (*i.e.* meat, hide, bones…) and secondary products, which can be exploited during the lifetime of the animal, such as milk, strength, fleece, manure… Very few theoreticians of the anthropology of techniques have proposed a classification of animal products; but of the rare ones who did, F. Sigaut (1980), distinguished four categories (body products, energy, behaviour and signs), and focussed on the product which can be obtained both when the animal is killed and when it is alive, *i.e.* hair. In spite of the lack of a true anthropological base, Sherratt’s rough binary opposition between “primary” and “secondary” products has been widely adopted by archaeologists and archaeozoologists for 35 years without question, except for the position of A. T. Clason (in Greenfield 1988).

The Sherratt's six main lines of arguments can be listed as follows:

– The exploitation of large mammals for their strength (carrying, draught) requires high technical skills, and cattle cannot be milked without the presence of the calf or the use of special sophisticated techniques, and wool did not exist before the Late Neolithic. The farming skills of the last hunters in the early Neolithic are considered as being too poor to solve these technical difficulties.

– In general, humans have lost the ability to digest lactose (disaccharide sugar) after weaning, and thus suffer serious digestive and physiological disorders when ingesting unfermented milk, because of uncontrolled bacterial fermentation of the lactose in the intestine. This is considered to have precluded the mass consumption of milk. Neolithic consumption of dairying products would have required the use of fermentation techniques which seemed to Sherratt to be too sophisticated to have been used at the time of the first domestication or even before.

– Primitive cattle breeds produce too little milk for both the calf (which must continue to suckle for milk release) and its human masters for them to base their subsistence on dairying.

– The first evidence for ploughing, and for the use of carts, harnesses and yokes seamed to have appeared together with the first evidence of the use of horses, with the first representations of milking, with the increase in the diversity of the pottery related to the manipulation of liquids, and with the first evidence of woolly sheep and of fleece exploitation.

– These different innovations seamed to have appeared during the 4th millennium in Mesopotamia, then in the 3rd millennium both in Europe and North Africa, which suggests an invention which occurred in the Near East and then spread.

– These interactive innovations appeared to have strongly contributed to the profound economic, social and cultural changes of the 4th / 3rd millennia, which led to the first cities and to more complex societies.

Concerning milk, which is the main focus of this paper, the second and third arguments led Sherratt (1997: 205) to conclude: "It cannot be assumed that [milking] was practised from the beginning of domestication".

In this, Sherratt is in agreement with Sigaut (1980), who believes that the idea of milk exploitation (as well as all exploitation of the products of living animals except hair) was not present in the minds of early farmers because the last hunters who became these farmers would have ignored this possibility. But Sherratt's theory is in complete opposition to Poplin (1980: 17), who concluded, in French, shortly before the famous Sherratt papers, that "…l'état fragmentaire de la documentation ne permet guère mieux qu'une forte présomption pour la production laitière dès le début du Néolithique; mais cette présomption est forte, et il serait déraisonnable de penser que les hommes se privaient de cette ressource…" (see also a very similar proposal by Gouin 2002).

Later on, Bogucki (1982, 1984) criticized the conclusions of Sherratt, pointing out the early Neolithic cattle kill-off profiles from the LBK site Brzesc Kujawski (5th millennium) and, in general, the presence of ceramic sieves dating to the 6th millennium in central Europe. Later on, taking these arguments into account, Sherratt (1997) accepted that "milk-drinking, while secondary, may have emerged during the first spread of farming". However, he did not take into account the arguments of Chapman (1982 & in Greenfield 1988; see also Whittle 1985: 209-10), which mostly stated that the "secondary products revolution" model was very simplistic in relation to the complexity and regional diversity of the Early and Middle Neolithic European societies. On the contrary, several authors argued for the "secondary products revolution" theory (see for ex. Entwistle & Grant 1989, Hodder 1990), especially Greenfield (1988, 2002), who based his argument upon osteological harvest profiles from sites in the former Yugoslavia. Now that it is generally admitted that milk may have been used (long?) before the 4th-3rd millennia farming "revolution" (*i.e.*, the emergence of ploughing, of the wheel and of the use of the horse) in Europe and the Near East (see the last paper that Sherratt wrote in 2006, shortly before his death), one of the main objectives today is to obtain a better evaluation of the importance of dairy products during the Early and Middle Neolithic periods, but excluding the very first stages of animal domestication.

In this paper, we briefly review recent biochemical, isotopic and palaeogenetic evidence and examine the new osteoarchaeological methods and results more deeply. We will focus mainly on the Near East and Mediterranean Europe. We also attempt to take into account as much evidence as possible, including that published by French scientists, which whether published in French or English has surprisingly been almost ignored in this debate until now.

BIOCHEMICAL, ISOTOPIC AND PALAEOGENETIC EVIDENCE FOR NEOLITHIC DAIRYING

Remnant fats in archaeological pottery vessels

It has been possible to characterise, over the last thirty years, organic residues adhering to Neolithic pottery sherds through biochemical techniques. This enables definition of the use of the different kinds of vessels from Neolithic sites, and helps to trace the emergence and the growing importance of milk processing during the Neolithic period. However, the characterisation of milk residue in relation to other lipidic food, namely animal fat, required much trial and error. After several fairly convincing residue analyses (*e.g.* Bourgeois & Marquet 1992, Bourgeois & Gouin 1995), Dudd & Evershed (1998) achieved the decisive step. They observed and experimentally demonstrated that the short chains of fatty acids, which could have been used as good discriminators between milk residues and adipose fat, disappear during the burial period because of diagenetic hydrolysis and subsequent water dissolution. At the same time, they also showed that the C18:0 fatty acids are actually preserved in the absorbed organic residues of archaeological pottery vessels, and that their $\delta^{13}C$ values in ruminant dairy fats are 2.3‰ lower than in ruminant adipose fats, because of physiological differential isotopic fragmentation processes. The extraction of the C18:0 fatty acids by gas chromatography-combustion (GC-C) and the measurement of the $\delta^{13}C$ values by isotope ratio mass spectrometry (IRMS) consequently enabled detection of the dairy origin of the fat residues. These methods rapidly gave good results, demonstrating the use of milk during the Late Neolithic in several locations (see *e.g.* Regert *et al.* 1998, 1999).

Later on, Copley *et al.* (2003, 2005a, b, c) applied this technique to nearly 1000 pottery sherds from 14 British sites, 438 of them from the 5th millennium Neolithic. 25% of the Neolithic sherds presented dairy fatty residues. They conclude that "dairying was an established component of the agricultural practices that reached Britain in the 5th millennium" together with the Neolithic package. The kill-off profiles of animals on these sites suggested that the milk came mainly from cattle.

Craig *et al.* (2003) used the same method in order to test the correlation between milk and the so-called Copper Age "milk jugs" that Sherratt (1983) used as evidence for the generalisation of milk consumption at that time. They did not find fatty deposits that were clearly from dairy products in any of the sixteen jugs from four different sites in central Europe, although most of them yielded fatty deposits. However, they did find fatty residues of milk in some other types of pottery. These results show how difficult it is to rely upon only the morphological characteristics of pottery vessels as evidence of their use in dairying (see *e.g.* Gouin 1997).

Later on, Craig *et al.* (2005) applied the method to a series of 40 potsherds from two Early Neolithic sites in the Carpathian basin, dated respectively to 5959-5500 BC[1] (Starčevo Criş culture) and to 5800-5700 BC (Köros culture). Only twelve sherds yielded fatty residues, six of

1. All the dates in this paper are calibrated before Christ (BC).

them probably from milk products. They also provide evidence for the presence of mid-chain ketones which are lipid pyrolysis products and suggest that dairy products were heated in these potteries. This evidence suggests that early Neolithic people in this area heated milk, probably in order to drink it hot, alone or mixed with some other food (cereals), and thus that most of them were able to digest the lactose sugar, which is not hydrolysed by cooking.

Isotopic evidence for management of cattle for dairying

Though much less frequently cited, isotopic evidence for Neolithic management of cattle for dairying provides complementary information. At the origin of this evidence is the strange culling profile at the Paris-Bercy Middle Neolithic settlement site: in addition to the classic age class of 2-4 years exploited for meat, A. Tresset (1996, 1997) for the first time revealed a very sharp 6-9 months' peak (Fig. 1a). According to her interpretation, this peak could not be explained except for the elimination of some of the calves at the end of the summer season either in order to restrict the number of animals to be foddered during the winter season, or because they were no longer useful for milk exploitation (Neolithic cows could not release their milk without the presence of the living calf, Balasse 2003). Therefore, Tresset's hypothesis, called "post-lactation slaughtering" would have been evidence of cattle management for dairying.

In order to determine the weaning age of the calves at Bercy, Balasse *et al.* (1997, 2000) studied the variations of the collagen $\delta^{15}N$ ratio at different heights in the dentine of the molars (Fig. 1b). Indeed weaning is a change from a milk diet (when suckling, calves are consuming an animal product, and thus may be termed carnivores) to a plant diet, which causes a decrease of about 3 parts per thousand of the $\delta^{15}N$. They observed that the weaning age was about 6-9 months old, making the "post-lactation slaughtering" hypothesis more likely, and thus herd management for dairying more probable. In addition, Balasse & Tresset (2005) found that the weaning age was earlier at Bercy than for modern natural domestic cattle populations (Fig. 1c). This can be interpreted as either a consequence of a shorter lactation period in primitive breeds, or as control of weaning by the herders.

Palaeogenetic data

The persistence of humans' ability to digest lactose sugar after the weaning age is due to the persistence of the lactase enzyme, which is itself due, in European peoples, to a single mutation, transmitted in a very simple Mendelian way with a single allele located at position 13.910 in the human genome (Enattah *et al.* 2002, Lewinsky *et al.* 2005). Based upon the ancient DNA of one Mesolithic and eight Neolithic European human skeletons, Burger *et al.* (2007) concluded that this mutation was not already present at a high rate before the Neolithic in European human populations, and that it increased in frequency during the Neolithic period. They suggest that this mutation was selected by environmental pressures during the Neolithic, *i.e.* for the selective advantage that was provided by the consumption of unfermented milk, long before the so-called "secondary products revolution". This suggests that the diet of European peoples would have significantly benefited from milk supply as early as the beginning of the Neolithic period.

Although biomolecular replications and confirmation on a larger scale are awaited, this proposal would suggest that milk played an important role in the Neolithic diet, in contrast to the Mesolithic hunter-gatherer diet, and even in the Neolithic demographic transition which led to the progression of this new way of life from the centre (6500 BC) to the most remote parts of north-western Europe (4th millennium). Milk is indeed four times more efficient as a conversion of grazing to the benefit of the human body than hunting, which could have helped to increase the life expectancy of Neolithic people (Vigne, in press). This is especially true for the youngest humans, as it prolongs the beneficial effects of

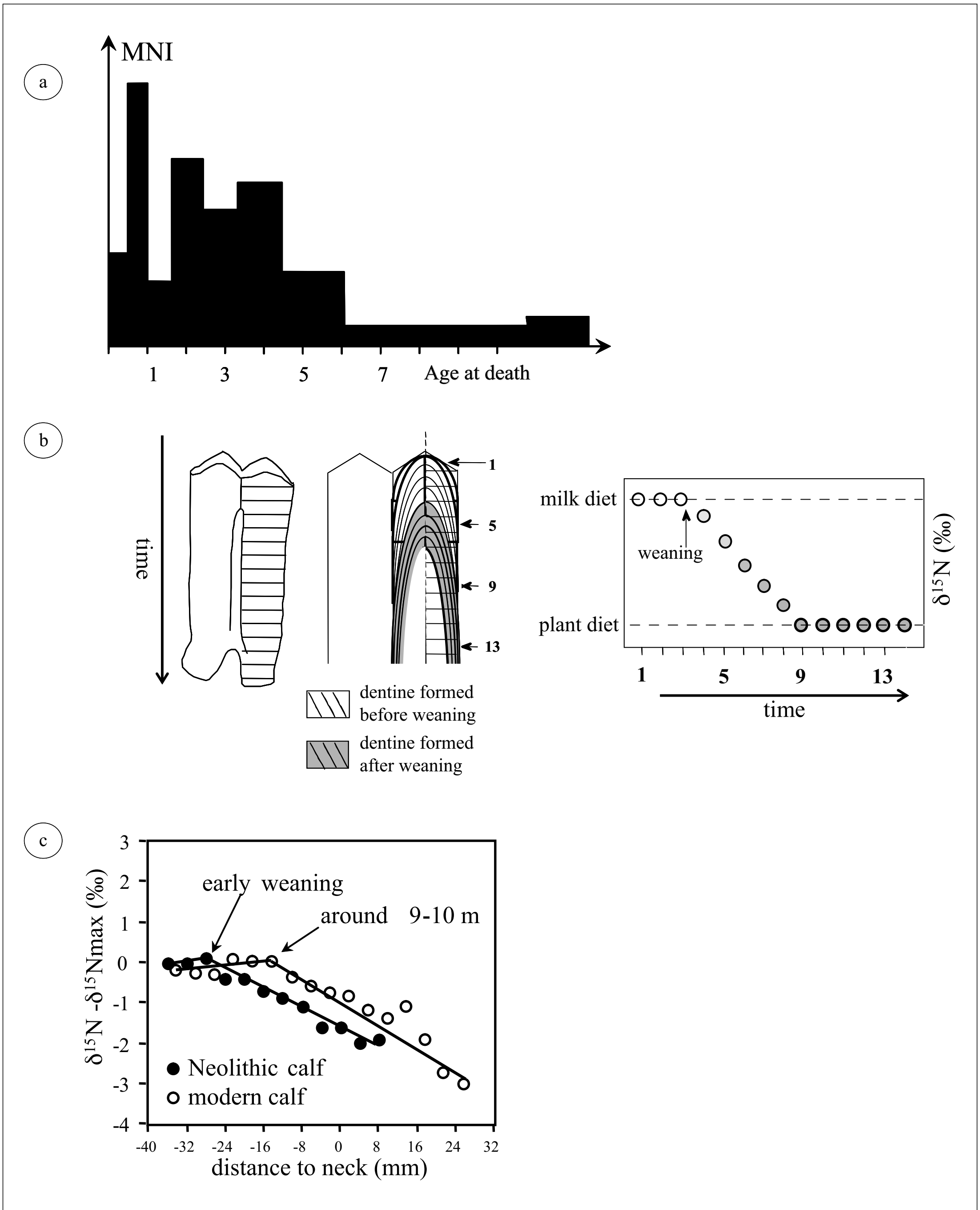


FIG. 1. – Evidence for milk exploitation of cows in the 4th millennium Middle Neolithic (Chasséen) at the site of Paris-Bercy, through detection of a signal for post-lactation slaughtering: a) Paris-Bercy cattle slaughtering profile (after Balasse *et al.* 2000); b) serial micro-sampling of dentine for the measurement of the ^{15}N rate in calves' cheek teeth (after Balasse *et al.* 2000); c) comparison of the weaning profile of a Neolithic Bercy calf with that of a modern calf which was weaned naturally without any human intervention (after Balasse & Tresset 2002).

milk (proteins, fats, but also calcium supply) long after the weaning age.

INITIAL CONCLUSION

Biochemical, isotopic and palaeogenetic evidence is just beginning to provide evidence that dairying and using transformed dairy products emerged earlier than the 4th-3rd millennia and were common practices in the temperate and northern Europe Neolithic. These practices seem to have been present as early as the earliest stages in Britain, but also in central Europe, about 5900-5700 BC. They possibly favoured the increase in frequency of the lactase persistence as early as that time or earlier. Consequently, although they do not directly invalidate the "secondary products revolution", they suggest that at least one of its components, dairying, could have emerged much earlier, and may be considered separately from the others.

However, these methods give little information about the relative roles of cattle, sheep and goats in milk production (see however Mirabaud *et al.* 2007), and there is so far no evidence in the Near East or in the Mediterranean area, that is, no evidence before the 6th millennium, which is nearly 30 centuries after the beginning of animal husbandry.

OSTEOLOGICAL METHODS AND EVIDENCE FOR NEOLITHIC DAIRYING

The different kinds of strategies for management of domestic ungulate herds produce different patterns for the slaughtering age of animals (Ducos 1968). For example, based upon modern sheep herds in Turkey, Payne (1973) demonstrated that meat production requires a massive killing of young and sub-adult males between 6-18 months, while specialised dairy farming is characterised by the slaughtering of very young lambs, less than two months old; wool exploitation is accompanied by the highly frequent slaughtering of both males and females (see also Helmer 1992). Obviously, these osteoarchaeological techniques should also provide interesting information about the history of milk (and all "secondary products") exploitation during the Neolithic period. In addition, they should provide more direct information on the exploitation of each species, cattle, sheep or goat, for dairying, together with the practices that farmers improved upon from the beginning to the end of the Neolithic period.

However, Greenfield (2005: 15) rightfully wrote that "most discussions of the origins of secondary products exploitation ignore the most relevant data category — the skeletal remains of the animals." Based upon the study of a group of Neolithic bone assemblages for the Balkan area, he constructed numerous kill-off profiles and, based upon Payne's models, he used them for discussing the "secondary products revolution" (Greenfield 1988, 2002; Greenfield & Fowler 2005, Arnold & Greenfield 2006). In parallel, Helmer (1992, 1995), Vigne (1998), Vigne & Helmer (1999), Helmer & Vigne (2004) and Helmer *et al.* (2005) did the same for sites of the Near East, Greece and the north-western Mediterranean area.

Of course osteoarchaeological data have several biases and limitations which have been analysed by authors, *e.g.* Cribb (1984, 1985), Chapman and Hesse (in Greenfield 1988) and, more recently, Halstead (1998). According to the latter, one of the main limitations is the equifinality, *i.e.* varying production strategies may produce similar harvest profiles. Halstead (1998) rightfully considered that "partial and biased survival and retrieval" are the main sources of equifinality but he demonstrated that they tend not to artificially create a milk pattern, but to obscure an existent one. He suggested that the best way to overcome this difficulty consists in questioning the archaeological validity of each bone assemblage, and in increasing the number of data in order to have as large as possible a spectrum of intra-site and inter-site comparison and cross-validation for a specific chronological period. As we have already pointed out (Vigne *et al.* 2005: 8-9), this strategy requires important advances for standardisation.

All the other limitations to the harvest profile method that have been raised can be solved by technical improvements, of which several are already available, although not widely known to Anglophone scientists.

Recent technical improvements

Even though disregarded by many authors (see *e.g.* Craig *et al.* 2005), important technical improvements have been achieved during the last 20 years. As we have recently stated (Vigne *et al.* 2005), they tend to:

– standardise and increase accuracy for age determination;
– increase taxonomic resolution;
– improve the quantitative processing of data;
– refine the models.

Standardisation and increased accuracy for age determination

Age at death can be determined based upon the epiphyseal fusion of the extremities of long bones or upon some other skull or post-cranial ontogenetic modifications. But this method is not very accurate (Wilson *et al.* 1982, Bassano *et al.* 2000, Ruscillo 2006) and it is difficult to process its results from a statistical point of view because it gives no precise date but only age range, and is biased, often in an undetectable way, by the differential preservation of the bones through time (Vigne 1984). Eruptions of the milk or definitive teeth, as well as the replacement of the milk teeth by the definitive ones and, to a lesser extent, the degree of wear on the crowns of the hypsodont cheek teeth are much better criteria for archaeologists (Ducos 1968, Helmer 1992). Age at death is estimated with reference to large series of modern jaws of known age.

The tooth-based age methods proposed by Ducos (1968), Payne (1973, 1987) then Grant (1975) have two great advantages in relation to the one proposed by Bökönyi (1970): several age classes allow better resolution and they define reproducible criteria (either well defined typologies or measurements) for each age class. The most notable recent improvement is that they are now all compatible (Table 1).

Table 1. – Determining the age at death by the archaeological cheek teeth of sheep and goats. Recently, archaeozoologists have had at their disposal good correspondence between the different age tables of Payne (1973, 1987; first columns and outlines in the eight last columns) and Grant (1982; second column), which are based on the shape of the enamel blades on the wear surface of the tooth (Hambleton 1999, cited by Greenfield 2005), and Helmer's age table (1995; see also Vila 1998; eight last columns), based on the decrease of the crown height of the cheek teeth, following the method of Ducos (1968).

Mandible ontogenic stages			CROWN / HEIGHT / COLLAR WIDTH (Ducos, revised Helmer)							
			Lower teeth				Uper teeth			
Payne	Grant (Greenfield 2002)	Suggested Age (years)	D_4	M_1	M_2	M_3	D^4	M^1	M^2	M^3
A	1-2	0 to 0.17								
B	3-7	0.17 to 0.5		5.0				3.0		
C	8-18	0.5 to 1		4.1	5.5			2.5	3.5	
D	19-28	1 to 2		3.5	4.9	5.5		2.0	3.0	3.4
EF	29-37	2 to 4		2.5	3.5	4.7		1.5	2.2	2.8
G	38-41	4 to 6		1.5	2.4	3.35		1.0	1.8	2.0
HI	42+	6+								

Hambleton (1999, quoted by Greenfield 2005) took a step towards standardisation by proposing a method of conversion from Grant's system of recording tooth wear to Payne's system. However, the method of measurement of the crown height in relation to the neck width proposed by Ducos (1968) is also very efficient, especially for isolated teeth, which are often much more numerous than tooth series still set in the bone, in Neolithic archaeological deposits. However, Helmer (1992: 45) has pointed out that the metric references used by Ducos for sheep and goats were erroneous. Helmer (1995) and Vila (1998) checked the Payne and Ducos criteria on several collections, confirmed Payne's criteria, corrected Ducos' criteria into a new grid, and provided a method of conversion from Payne's criteria to Ducos' criteria, for both inferior and superior teeth. Age determinations are more accurate because they can now frequently be based upon a cross-validation of the different methods. In addition, as seven age classes are available and well-defined, archaeozoologists can obtain a clearer picture of the Neolithic age pattern.
A similar method has been initiated for pigs (Bridault *et al.* 2000) but has not yet been completely attained. It must be developed for cattle (see however Balasse 1999). However, for both of these we already have good modern age references, which would provide good sets of refined data if all archaeozoologists actually used them with the goal of achieving the highest accuracy.

Increase taxonomic resolution for sheep and goats
Although they have very similar bone morphologies, sheep and goats have different behaviour and capabilities (e.g. Balasse & Ambrose 2005). Mixed kill-off profiles are therefore nonsensical in relation to the practices, and very difficult to interpret by archaeologists (Halstead 1998). Payne (1985) first proposed good criteria for distinguishing lower jaws, but they were mostly restricted to the lacteal teeth. Helmer (1995, 2000a) proposed complementary criteria for the lower definitive premolars, which have been separately confirmed by Halstead *et al.* (2002), based upon a very large set of present-day well-determined lower tooth series. The latter has also proposed criteria for the mandible bone and for the three lower molars. Our experience with several archaeological series, especially those which are more recent than the Late Neolithic, suggests however that they are less reliable and should be used together with the better criteria which have recently been proposed by Balasse & Ambrose (2005).
In any case, it is now possible to distinguish sheep and goat management in the Neolithic, as did Greenfield (2005) for certain sites of the central Balkans, and as we also did (Helmer & Vigne 2004, Helmer *et al.* 2005) for the Neolithic of the Mediterranean south of France (Fig. 2a). Based upon more than 20 profiles from this area, we observed that early Neolithic people exploited small herds of goats mainly for milk, while they used larger sheep herds for more mixed purposes; in the course of the Neolithic, sheep became more and more exploited for "secondary products" (Fig. 2b).

Improve the quantitative processing of data
Chapman (in Greenfield 1988) criticised H. J. Greenfield because he did not use any statistical test for his harvest profile comparisons; this criticism was all the more justified since H. J. Greenfield used very small samples, as we are very often constrained to do with Neolithic archaeozoological series. As for any quantitative archaeological data, the lack of statistical tests leads to misinterpretations. For example, Greenfield (2005: 27) wrote: "The Late Neolithic harvest profiles closely follow the pattern set for the Early Neolithic"; but a statistical comparison between the most important Late Neolithic profile (Vinča, N= 34) and the most important Early Neolithic profile (Blagotin, N= 137) indicates that they are not significantly similar at 5% confidence threshold (Spearman correlation coefficient: r'= 0.23, df= 5). Although Vigne *et al.* (2005) launched a new call for the use of statistics and multivariate analysis for age data, very few attempts have been carried out in this direction (see however Klein & Cruz-Uribe 1984: 57 *et seq.*, Tresset 1996, Vigne 2000, Haber *et al.* 2002).

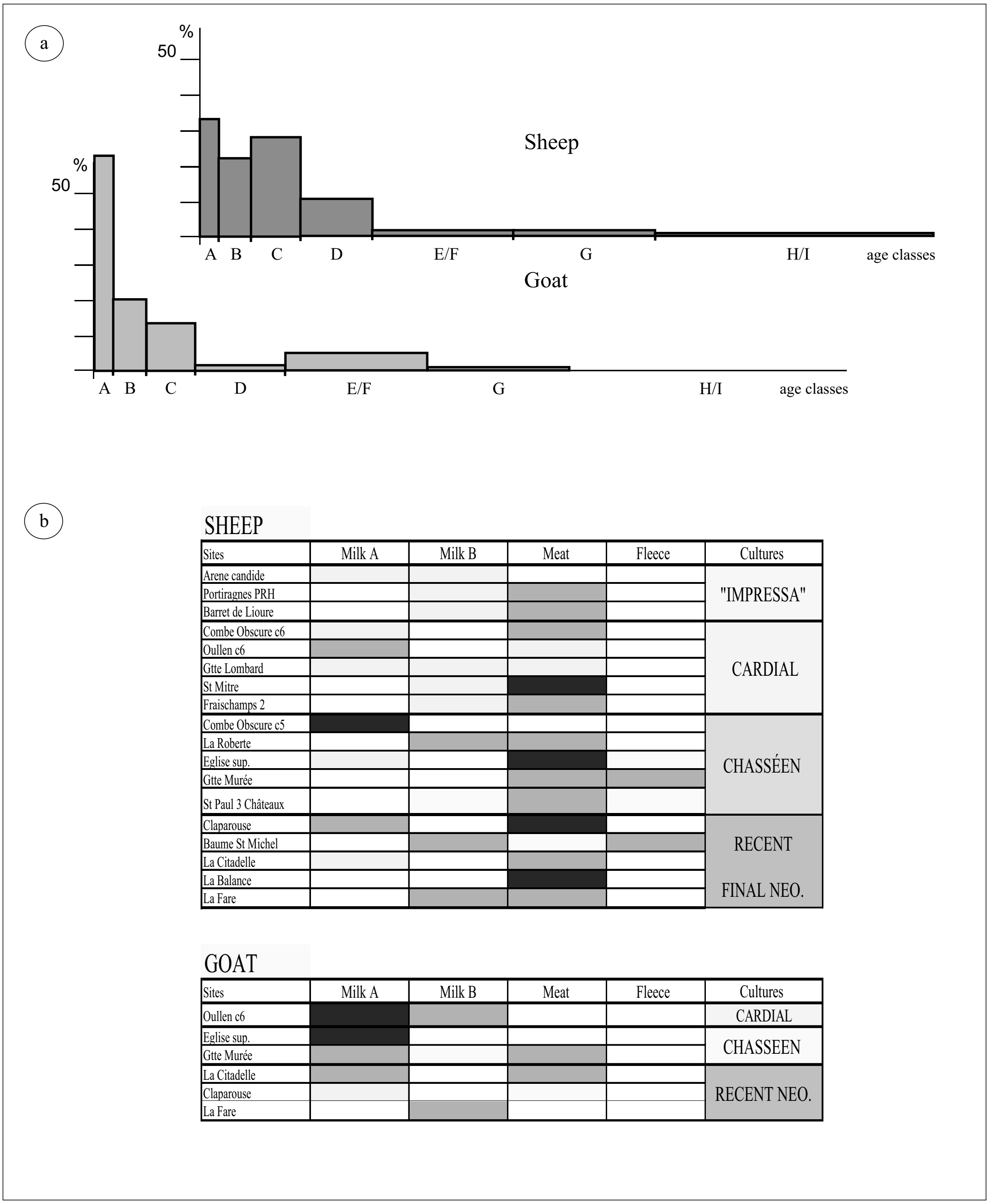


FIG. 2. – The discrimination between sheep and goat based on the lower cheek teeth has been possible for the last few years (Helmer 2000, Halstead *et al.* 2002). For example (a), on the Early Neolithic site (Cardial, 6th millennium BC) at Baume d’Oullin (Ardèche, France) it demonstrates that sheep were exploited for milk and meat, while goats were used for specialized milk exploitation (these are however “truncated” profiles, which correspond to seasonal occupations of the cave; Helmer & Vigne 2004). Eighteen Neolithic sites (b) in south-eastern France examined according to these methods revealed that sheep were mainly exploited for meat, while goats were more generally exploited for milk (Helmer & Vigne 2004; Helmer *et al.* 2005).

Another crucial point in the quantitative data processing is the unequiprobability of the age classes: for example, in Payne's system modified by Helmer (1995), the period of time covered by the different age classes varies from ca. two months to ca. 4 years (ca. 24 times more). For that reason, the relative importance of the shorter (younger) age classes is systematically under-estimated. Their frequency must be corrected as an inverse proportion of their probability (Ducos 1968: 13, Payne 1973; Fig. 3a).

This important bias may produce important changes. For example, Greenfield (2005) presented an important set of age data for the Neolithic sheep and goats in former Yugoslavia. He concluded that the harvest profiles indicated meat-oriented strategies during the whole Neolithic period, then shifted toward milk or hair/wool exploitation starting in the Late Neolithic and during the Bronze Age (Fig. 3c). He was also surprised that his profiles all significantly differed from Payne's present-day models for meat, milk or wool, because of a very low slaughtering rate for the A and B classes (less than 6 months), for which he found no explanation. However, for all these profiles, he used rough frequencies, without any probabilistic correction. Fortunately, he provided all the rough data in this paper, which enables us to build new corrected profiles (Fig. 3d). They are very different from those of Greenfield: (i) there are no more important discrepancies between them and Payne's model because of the lack of the youngest individuals of the youngest age; (ii) Neolithic profiles more or less fit either milk or meat profiles and not just meat; (iii) the evolution during the post-Neolithic period mostly tends towards specialised meat production, rather than towards "secondary products". And this new scenario does not fit Sherratt's hypothesis very well.

The same bias mars a large part of the demographic data that Greenfield & Fowler (2005) and Arnold & Greenfield (2006) recently published to demonstrate the "secondary products" revolution in Macedonia and early transhumance in south-eastern Europe, respectively, and renders all these conclusions questionable.

Increase and refine the models

Although they accept the importance of Payne's three basic theoretical models, several authors emphasized the necessity for some more experimental situations (see for example Tani 2002, Blaise 2005, Mutundu 2005), and to take into account other types of management strategies.

For example, as pointed out by Halstead (1998), it is possible to exploit the milk by keeping the young alive, Payne's model with an elimination of half the lambs before the age of two months being correlated with intensive dairying with production of surplus. Moreover, most of the present-day dairy exploitations spare the lambs, as was suggested by the agronomists of classical Antiquity (Columella VII, 3).

Let us take the example of the Kurdish semi-nomads of northern Khorassan (Iran; Papoli-Yazdi 1998; Fig. 4; see also Digard 1981). These are dairy sheep shepherds who sell the main part of their milk production as melted butter (*rughan*) and keep the rest for their own subsistence (cheese, yoghurt, butter). Lambing takes place between February 15th and March 10th. During the first month, the lambs are kept apart from the ewes a few hours each day in order to share the low fat milk between the sheep and the humans. During the second month, as the growing lambs require more milk, they are kept with the mothers, and the milk is not exploited. At the beginning of May, when the herds arrive on high-altitude pastures and the milk becomes fat enough for butter production, some lambs are killed for meat, while others are weaned and kept alive for future consumption. Such a strategy would produce a slaughtering profile completely different from the Payne milk model, although very diagnostic of another kind of milk exploitation strategy. Helmer & Vigne (2004) called it 'type B milk', and call the Payne model 'type A milk'. The B milk model is mostly characterised by the presence of a few B lambs (2 to 6 months), a high quantity of C lambs (killed for meat all through the year) and in general an important part of E-F older females which are killed when their lamb or milk production decreases.

Another issue concerns the effect of seasonal mobility on the harvest profiles. On the perma-

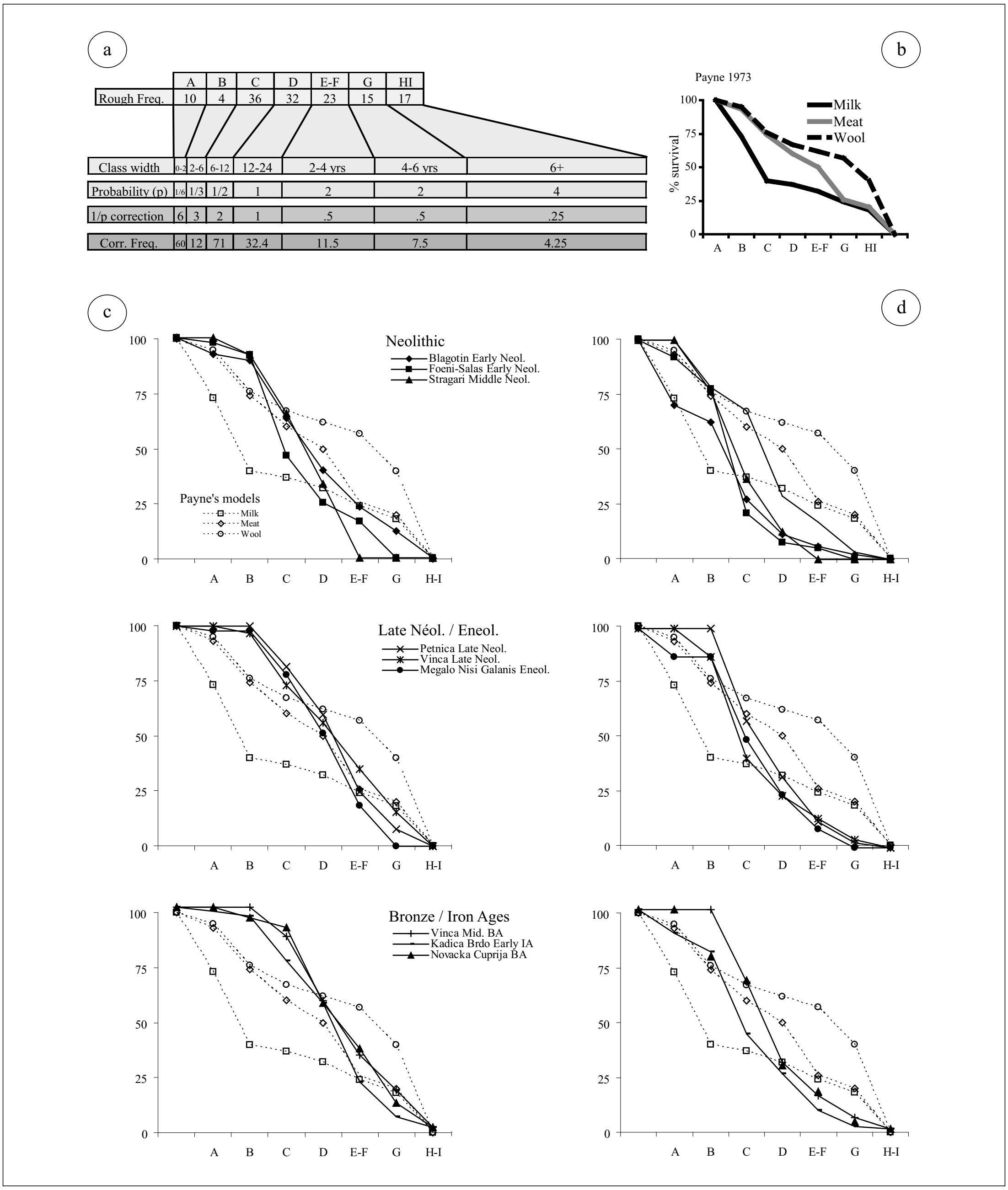


FIG. 3. – a) The seven age classes as proposed by Payne for determining the age at death of sheep and goats correspond to different widths, *i.e.* time duration. The probability (p) for an item to fall within any of them therefore differs from one class to another. Thus the rough frequencies have to be corrected by a factor which is equal to 1/p. In the survival diagram for sheep and goats from former Yugoslavia (c), Greenfield (2002) did not correct the rough frequencies of the age classes, which resulted in a strange situation in relation to Payne's three models (b), with very low slaughtering rates for young lambs. Here we corrected the data of Greenfield (d) and obtained results much in accordance with the Payne models (b). Whereas (c) is in favour of the emergence of "secondary products" during the Neolithic period in this region, (d) indicates that milk was widely exploited as early as the Neolithic, and that specialised meat or wool husbandry developed during the Late Neolithic and the Bronze Age.

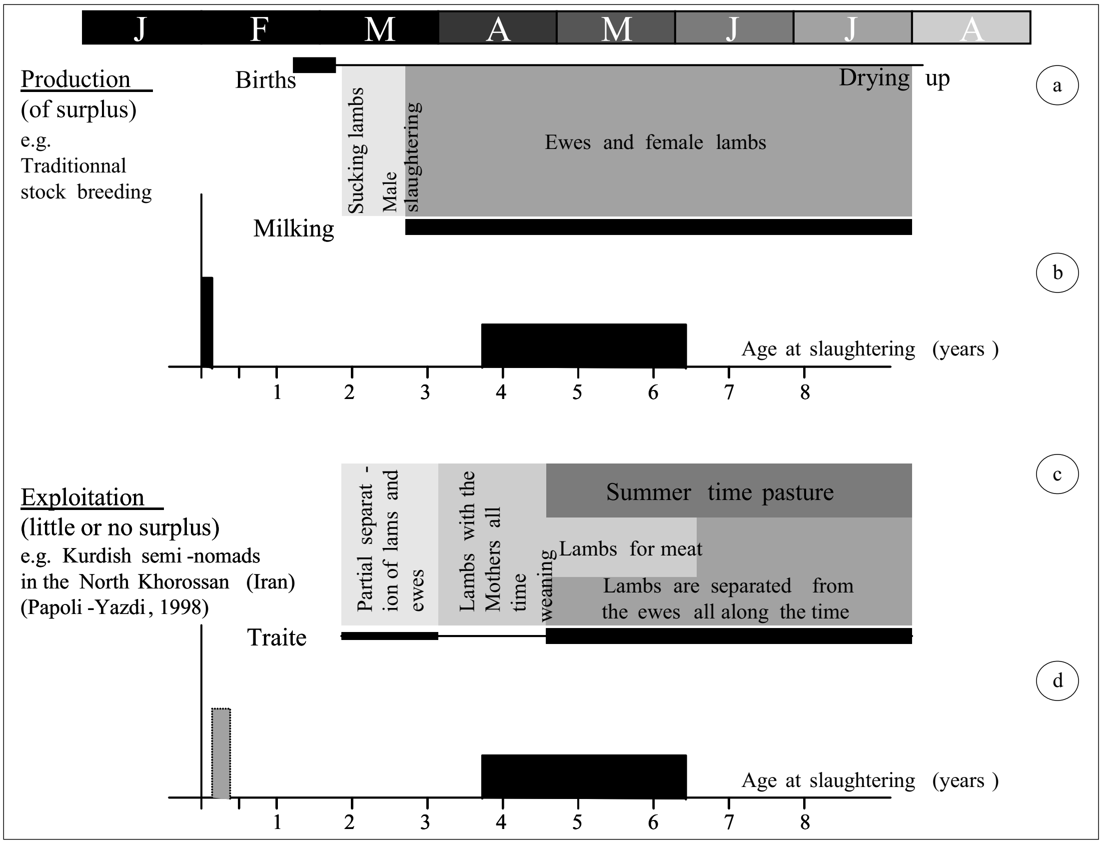


FIG. 4. – Comparison of modern patterns for milk exploitation of ewes ((a) and (c)) and of their possible archaeological signatures as harvest profiles (b and d, Vigne 2006). After Payne (1973) for (a) and (b), and Papoli-Yazdi (1991) for (c) and (d).

nent dwelling sites, animal remains provide evidence for all the different seasonal slaughtering events. But on the seasonal sites, only part of the slaughtering would leave evidence and the 'truncated' harvest profile would only relate part of the management strategy of the farmers. For example, let us imagine the summer food remains of the above-mentioned Kurdish shepherds: they will mainly contain the teeth of the lambs which have been killed at about three months old (class B of Payne); conversely, if the Kurds had eaten mutton in the plain dwellings where they spend the winter, we would have found there the bones of the older females killed because of decreased usefulness (classes E-F or G of Payne) and of some older lambs used for meat consumption (classes C or D depending on the meat strategy). The summer profile however can be easily recognized as a truncated one, because the overwhelming proportion of very young slaughtered lambs would be totally incompatible with the survival of the herd. Such 'truncated profiles' are frequent on seasonal archaeological sites, such as the caves of southern France (see the goat profile of figure 1; Helmer *et al.* 2005). Conversely, the winter profile cannot be differentiated from a complete annual profile, and therefore constitutes a trap for archaeozoologists, who can avoid it only by regional analyses including both the summer and winter sites.

From a more general point of view, based on an analysis of both present-day (see also Rendu

2003: 320) and archaeological profiles, we proposed adding two more to the three Payne models (Helmer & Vigne 2004). Each of these types is represented in figure 5 by an archaeological example, which also illustrates the possible discrepancies in relation to the theoretical models, especially seasonal truncations. Of course these five models cannot describe all the possible situations, and intermediate or different strategies may produce many other harvest profiles. It seems however, that these enable description of all the basic situations better than Payne's three models do; adding more models would be more confusing than useful.

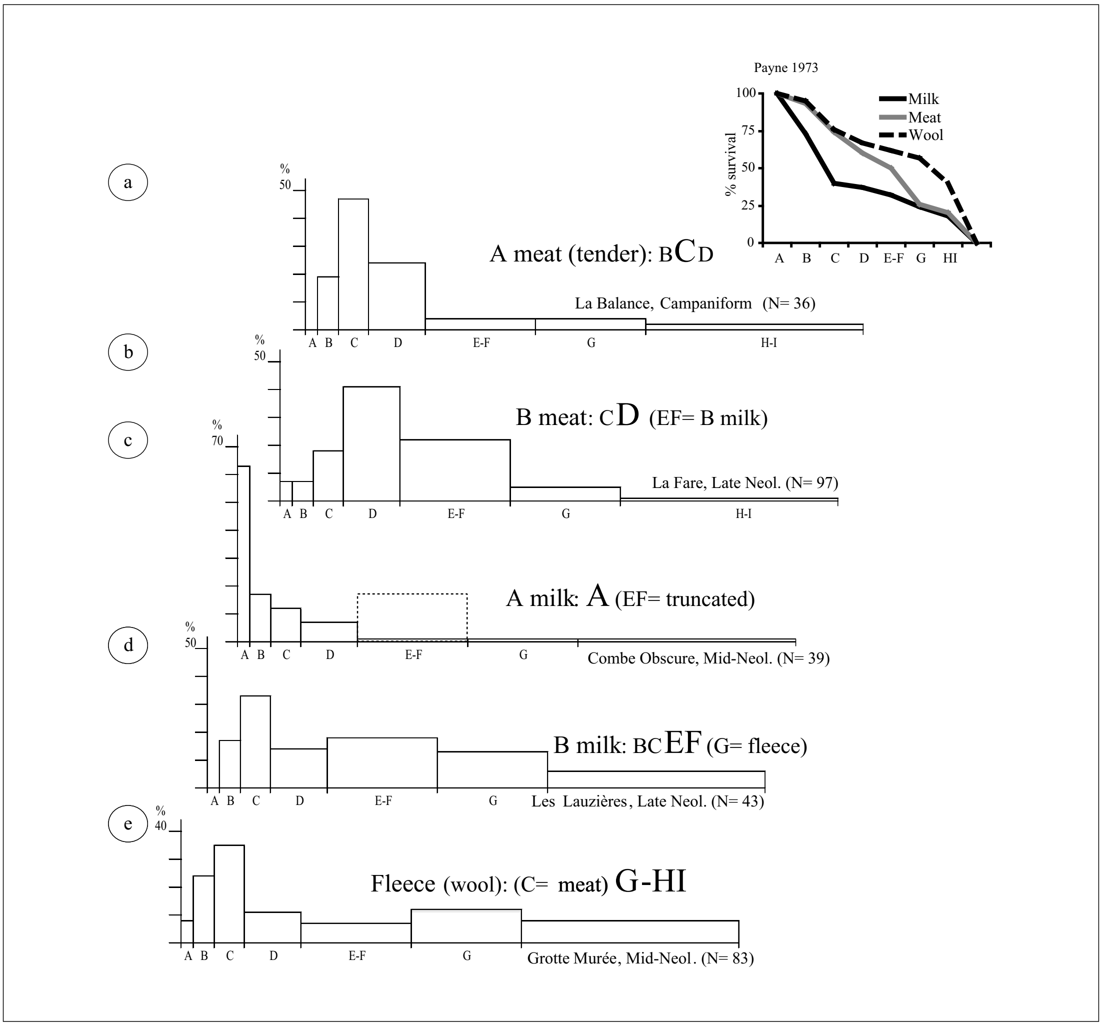


FIG. 5. – Illustration using actual archaeological profiles (N = number of teeth) based on the three Payne models: (a) meat (class C dominates, B and D are secondary classes); (c) milk (although truncated according to season; hatching shows the correct model; domination of class A); (e) wool/hair (domination of classes G and HI, however mixed here with meat exploitation of classes B and C). (b) and (d) are actual archaeological representations of the two new models that we proposed (Helmer & Vigne 2004) for late slaughtering for meat (class D dominates, although here mixed with an EF slaughtering due to the slaughtering of milk ewes) and for milk exploitation without slaughtering of the very young lambs (domination of class EF, here perhaps associated with hair exploitation), respectively.

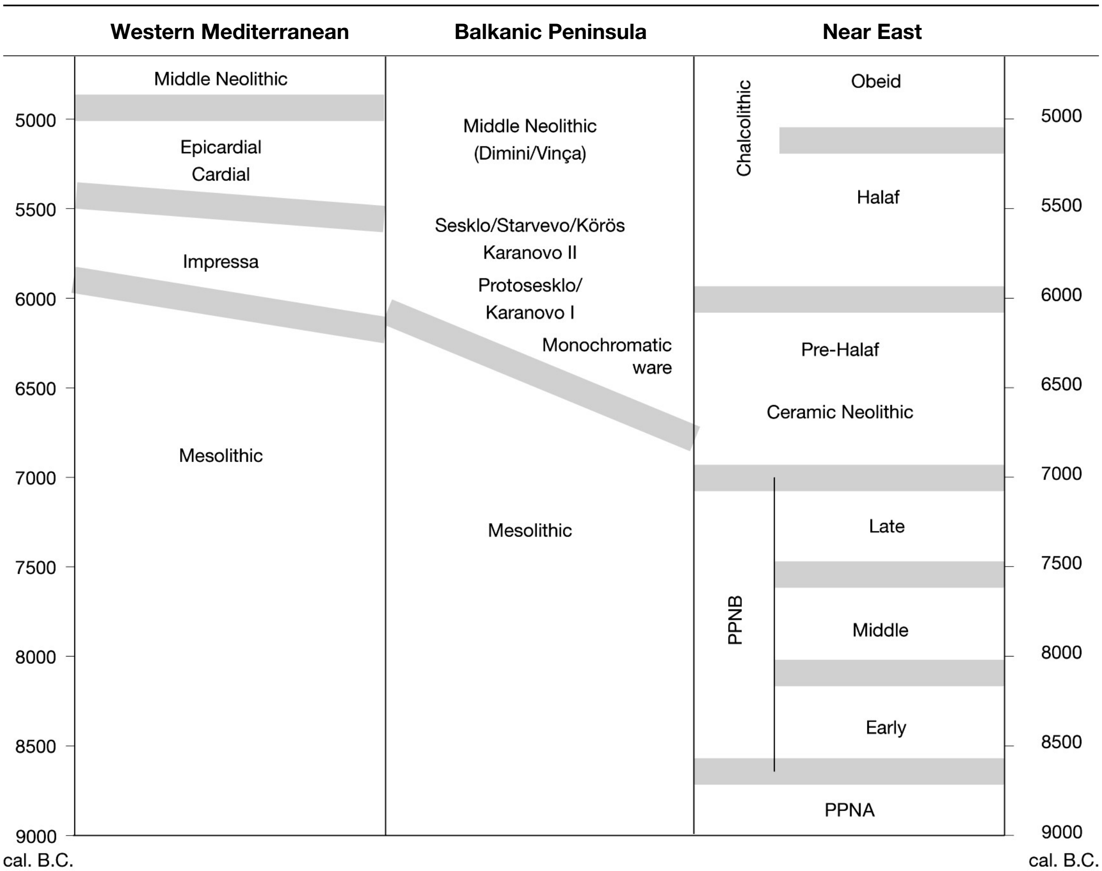
Archaeozoological evidence for Early Neolithic dairying

We will examine the data for sheep and goats, then for cattle, from the latest early Neolithic periods (western Mediterranean basin) to the earliest ones, the latter only being represented in the Near Eastern Pre-Pottery Neolithic. In order to help non archaeologist readers, Table 2 simplistically summarizes the main chronological points of reference for this archaeological journey.

Sheep and goat (Caprini)

For the *Impressa*, Cardial and Epicardial layers of the north-western Mediterranean areas, dating to the 6th millennium (Fig. 6), Vigne & Helmer (1998) and Helmer & Vigne (2004) described typical meat profiles of type A (Portiragnes, St Mître[2]), typical (although truncated) milk profiles of type A (goats of Baume d'Oulen, Arene Candide, according to the data of Rowley-Conwy 1997), and fairly typical milk profiles of

Table 2. – Main cultural complexes of the beginning of the Neolithic in the Near East, the Balkan region and the north-western Mediterranean, with dates (calibrated radiocarbon datings), according to Lichardus & Lichardus-Itten (1985), Cauvin (2000) and Mazurié de Keroualin (2003). This simplistic presentation only aims to give the main chrono-cultural points of reference to the non specialist reader.



2. Most of the archaeozoological data cited in the next paragraphs have been produced by one or the other of the two co-authors of this paper, and are referenced in Helmer & Vigne (2004). All the data which have not been produced by one of them are referenced to their author or in Helmer *et al.* (2007).

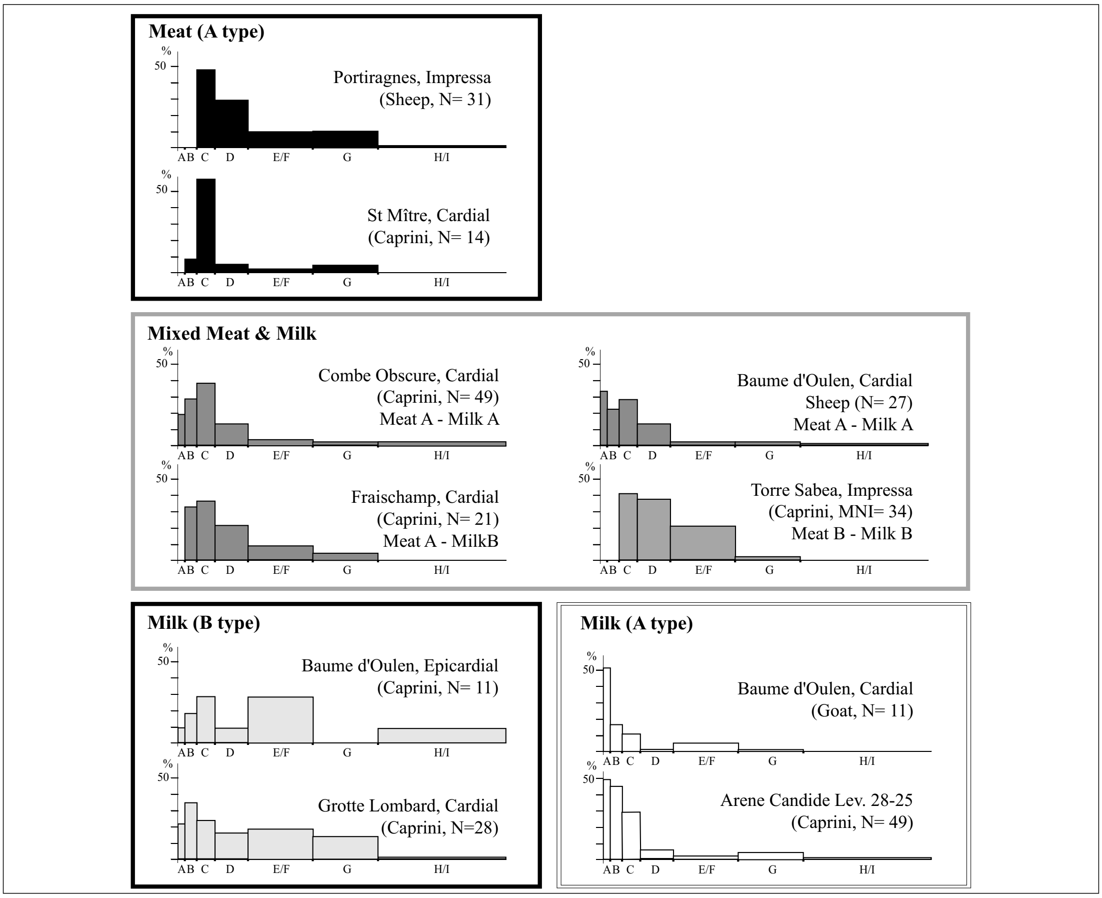


FIG. 6. – North-western Mediterranean sheep/goat harvest profiles dating to 6th millennium BC Early Neolithic sites and their interpretation according to the five models of figure 5 (Vigne 2003, Helmer & Vigne 2004).

type B (Grotte Lombard and Epicardial of the Baume d'Oulen). There are also mixed profiles with both tender meat and type A milk exploitation at Baume d'Oulen (Cardial sheep), Combe Obscure and Fraischamp. In southern Italy, there is a mixed profile with type B meat and type B milk (Torre Sabea; Vigne 2003a).
In the Balkan area (Helmer 2000a, and after the data of Greenfield 2005), there are still few profiles for the late 7th and the early 6th millennia earliest stages of the Neolithic. However, we found a large variety of situations (Fig. 7), with the type A meat profile at Foeni Salaş, mixed A milk and A meat profiles for the sheep at Dikili Tash, B milk for the goats of the same site and typical A milk on the large bone assemblage of Blagotin.
In the Near East (Helmer *et al.* 2007), during the first half of the 7th millennium, *i.e.* pre-Halaf and other early ceramic Neolithic periods, there is no pure meat profile (Fig. 8). But there are many different kinds of mixed profiles, combining in different degrees A or B types of meat production and A or B types of milk exploitation. In addition, there are at least two meat profiles (one each of types A and B) with clear evidence of hair exploitation, at El Kowm 2 (Helmer 2000b) and Tell Sotto (Helmer unpublished) respectively.

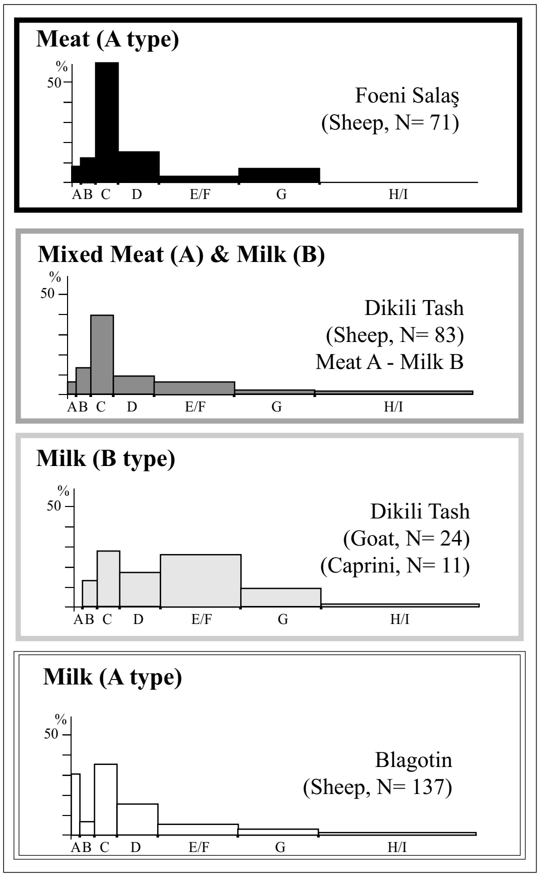


FIG. 7. – Balkan sheep/goat harvest profiles dating to 7th millennium BC Early Neolithic sites and their interpretation according to the five models of figure 5 (Helmer 2000, Greenfield 2005).

Farther back in time in the Near East, the data of the Late PPNB, *i.e.* the second half of the 8th millennium, also provides only mixed meat and milk profiles (Fig. 9). Most of these are mix type A meat with type B milk, but there are also type B meat with type B milk and type A meat with type A milk (Halula, according to the data of Saña Segui 1999).
There are few profiles for the earliest stage of animal domestication, *i.e.* the first half of the 8th millennium Middle PPNB (Fig. 10). However, they also provide definite evidence of milk exploitation. Of course, the earliest known profile at Çafer (east) is dominated by type A meat, but a rather high proportion of EF suggests a low exploitation of milk (type B). The following phase at Çafer and the Middle PPNB layers at Aswad give clear mixed profiles with tender meat and type B milk exploitation (and perhaps hair at Çafer). Milk exploitation is more significant at Halula, with a high elimination of very young lambs. In Cyprus, at Shillourokambos, sheep seem to have been exclusively exploited for milk, without any elimination of young animals.
Table 3 gives a quantitative summary of the available data. Out of 36 profiles of the early stages of the Neolithic in the northern Levant and on the northern shores of the Mediterranean, 30 are mixed meat and milk profiles, *i.e.* more than 80%. 19% are pure milk exploitation profiles, either type A or B, and milk exploitation is indicated as early as the first half of the 8th millennium at Shillourokambos. Pure meat exploitation has been found in only four sites out of 36. Even if the archaeological, chronological, environmental and cultural contexts of this evidence should be analyzed more deeply, it is now clear that, whether A or B, the milk of sheep and goats was exploited as early as the first stages of the Neolithic in the Near East and in Mediterranean Europe as well. It also appears that goats and then sheep were first exploited for their milk in all these periods.

Cattle

– What is the evidence for cattle dairying?
Unlike sheep and goats (Balasse 2003), which can be milked even when the young are dead or have been killed, cows need their calves' presence to release their milk. This is due to a physiological milk release reflex which is stimulated by the physical contact between the cow and its calf, which no longer exists in the selected breeds of the modern milk cow. Thus traditional cattle herders who wished to exploit milk had to keep a large quantity of calves until weaning, and to at least partly share the milk from their mothers.
Therefore, contrary to the type A milk model discussed above for sheep and goats, the exploitation of cows' milk should never require any

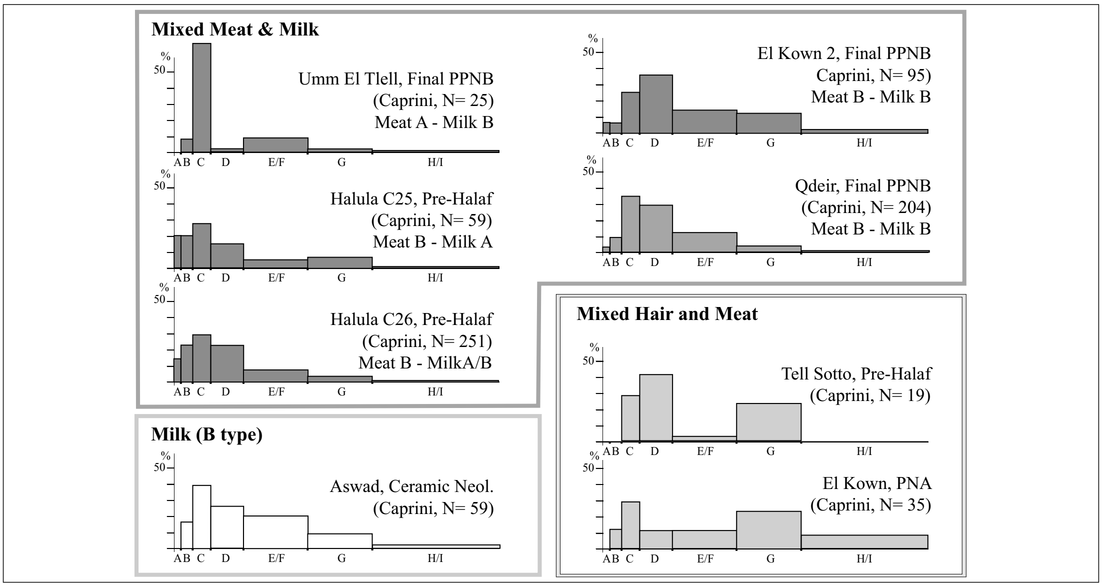


FIG. 8. – Northern Levant sheep/goat harvest profiles dating to final PPNB and ceramic Neolithic (7th millennium) sites and their interpretation according to the five models of figure 5 (Helmer *et al.* 2007, this volume). Data from Qdeir are from Gourichon (2004).

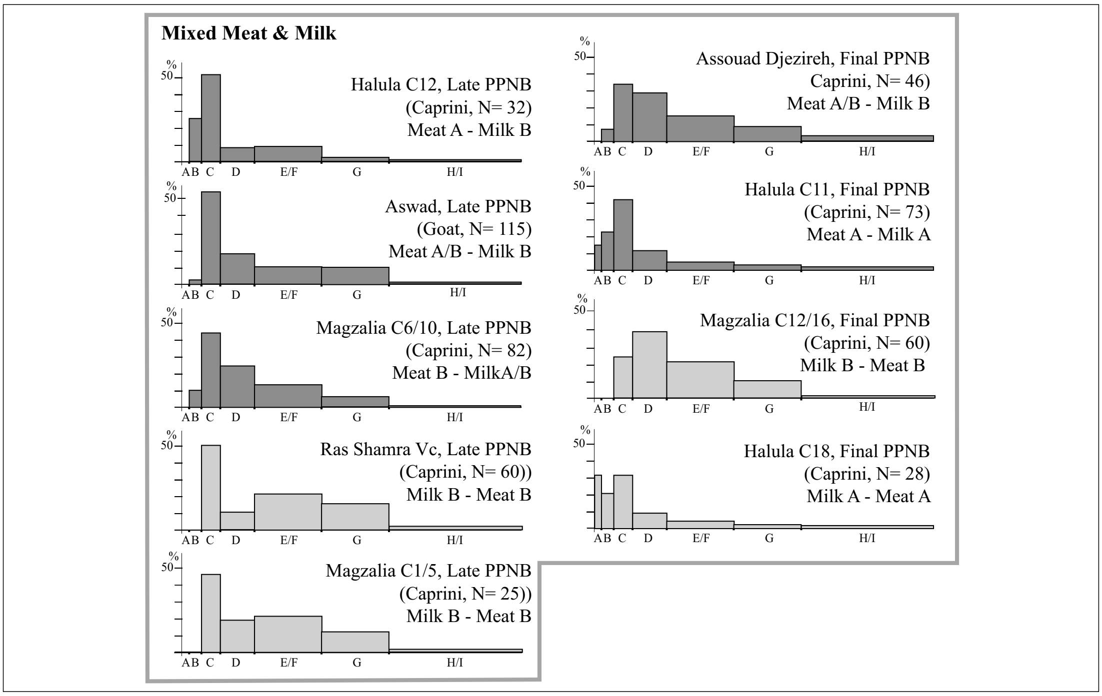


FIG. 9. – Northern Levant sheep/goat harvest profiles dating to late PPNB (second half of the 8th millennium) sites and their interpretation according to the five models of figure 5 (Helmer *et al.* 2007, this volume). The light grey profiles are dominated by milk exploitation, whereas the dark greys reflect a dominance of meat production.

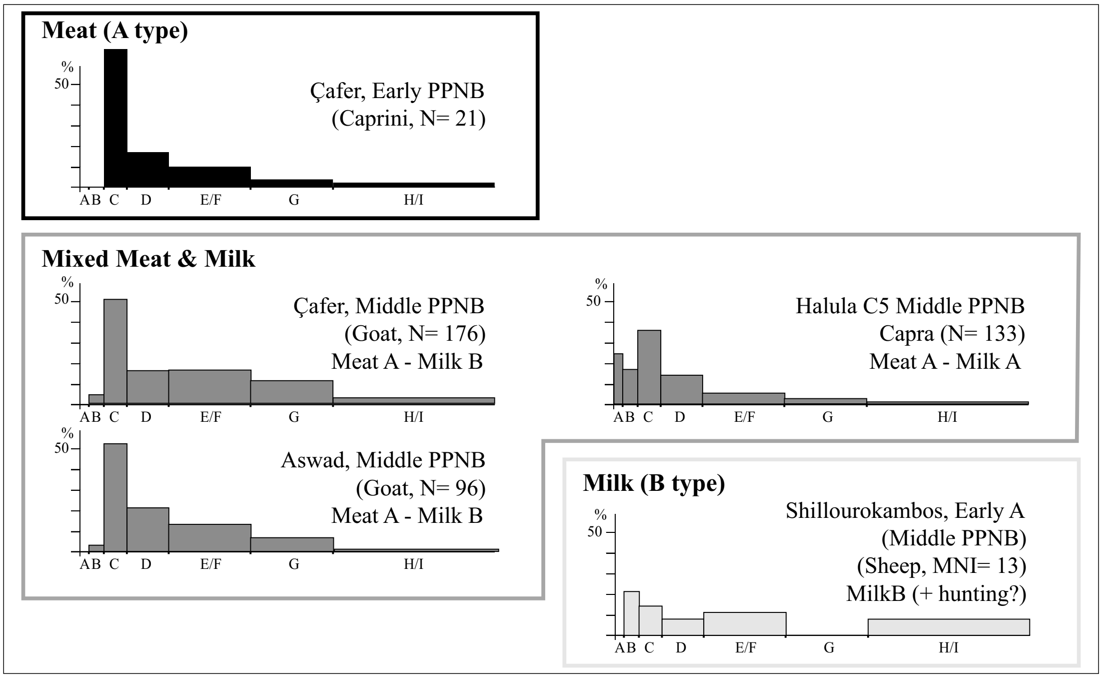


FIG. 10. – Northern Levant sheep/goat harvest profiles dating to early and middle PPNB sites (late 9th and first half of the 8th millennia, respectively) and their interpretation according to the five models of figure 5 (Helmer *et al.* 2007, this volume).

TABLE 3. – Frequencies of the main types of harvest profiles of sheep and goats which have been examined in this paper for Near Eastern and Mediterranean Early Neolithic periods.

		Total	Meat	Mixed Meat-Milk	Milk B	Milk A	Hair
NW Medit.	6th mill.	10	2	4	2	2	0
Balkans	7th mill.	4	1	1	1	1	0
Near East	7th mill.	8	0	5	1	0	2
	2nd half 8th mill.	9	0	9	0	0	0
	1st half 8th mill.	5	1	3	1	0	0

slaughtering peak of newborn calves, unless people employed practices which could substitute the presence of the calf during milking, such as blowing into the rectum or the vagina of the cow or using calf hides (Sherrat 1991: 277-279, Balasse *et al.* 2000). This is one of the reasons why it has been so difficult thus far to acquire archaeozoological evidence for Neolithic cattle dairying by the way of harvest profiles.

As there is a lack of modern age profile references for traditional milk exploitation of cattle, “post-lactation” slaughtering peaks (see above) are one of the rare ways to demonstrate Neolithic dairying. For the present contribution, we therefore tracked the presence, in the slaughtering profiles, of a peak for 4 to 8-year-old cows on the one hand, and a post-lactation slaughtering peak (5-9 months) as defined by Tresset (1996) and

Balasse *et al.* (1997, 2000), on the other. This quest was however hindered by the low number of published harvest profiles for cattle, as the age classes for most of them are too broad to be used to detect any "post-lactation" peak, and by the low number of cattle bones on most of the Early Neolithic Near Eastern and Mediterranean sites.

– Early Neolithic "post-lactation" and indications of cow kill-off

Cattle harvest profiles which indicate post-lactation slaughtering such as at Paris-Bercy seem to be rather frequent in the Middle Neolithic in northern France, but also in the large open air sites of southern France (Fig. 11; Villeneuve Tolosane, Fontaine 2002; Le Moulin, La Roberte, Le Gournier, Bréhard 2007). The profile that Greenfield (2005) published for the Middle Neolithic site Stragari (former Yugoslavia) also seems to show a post-lactation peak. For Le Gournier, Louviers and Stragari, the post-lactation peak is associated with a peak of killing off milking cows. Louviers, Villeneuve Tolosane and Stragari also show a peak of very young calves (less than one month). There are also post-lactation peaks in some profiles of the Early Neolithic of the north-western Mediterranean, such as Baume d'Oulen (southern France) and Trasano (southern Italy). This second site also shows a peak of very young calves; the absence of subadult or adult cattle on this site suggests that the profile is obviously truncated, probably because of seasonal mobility of the herders (Vigne & Carrère, unpublished). In the Balkans, the Early Neolithic site at Blagotin (Greenfield 2005) also seems to show a seasonal truncated profile with very high kill-off rates for very young calves (less than one month) but also with a peak of 6 to 12 month-old calves which would fit a post-lactation kill-off well. Thus, post-lactation slaughtering seems to have existed in western and central Europe during the Early and Middle Neolithic, ca. 6-5th millennia BC. It is impossible to tell if it existed in the Near Eastern Neolithic, since there are no cattle profiles available with refined age data for between 6 and 24 months.

Except for the three profiles already cited, cattle harvest profiles are very few for the early phases of the Neolithic, including in the Near East (Fig. 12). However all of them present fairly clear peaks of milking cow kill-off. At Tell Aswad (Damascus), the peak is not very developed during the Middle PPNB and Late PPNB, but in the second period, clear evidence appears for the use of cattle strength (Helmer in press). The kill-off peak is very developed during the Late PPNB at Ras Shamra CV, and the question arises as to whether this peak is overlapping a second peak which may result from the exploitation of the animals' strength. Clear peaks of female kill-off are also evident in the three profiles from the Balkans, Dikili Tash (Helmer 1992, in press) and the two Karanovo profiles of Vinča (Greenfield 2005), which are however much more recent (4th millennium). They are also present in the profile of Torre Sabea (late 7th millennium) in southern Italy, where milk exploitation of cattle is demonstrated by several other arguments (Vigne 2006). On the French site Corneilla (Pyrénées-Orientales), cattle are few but they are only females killed between the ages of 4 and 8.

Thus, though not numerous (only six), the cattle harvest profiles which are available for the early stages of the Neolithic (8th to 6th millennium) in the Near East and Mediterraenean Europe, strongly suggest that cow milk was exploited at that time. Moreover, it also seems clear that cattle were commonly exploited for their strength as early as the Middle PPNB (first half of the 8th millennium cal BC) in the Near East.

– The question of the high frequency of very young calves

In six of the ten Early Neolithic profiles that we examined, we observed a high rate of very young calves, which had been killed before the end of their first month. This has also been observed in three of the seven Middle Neolithic profiles, together with the post-lactation slaughtering peak. The proportion of these newborn calves reaches very high levels for some sites, but this is only because the corresponding profiles are truncated by seasonal practices. This slaughtering peak for newborns could be interpreted as the consequence of a high natural birth mortality,

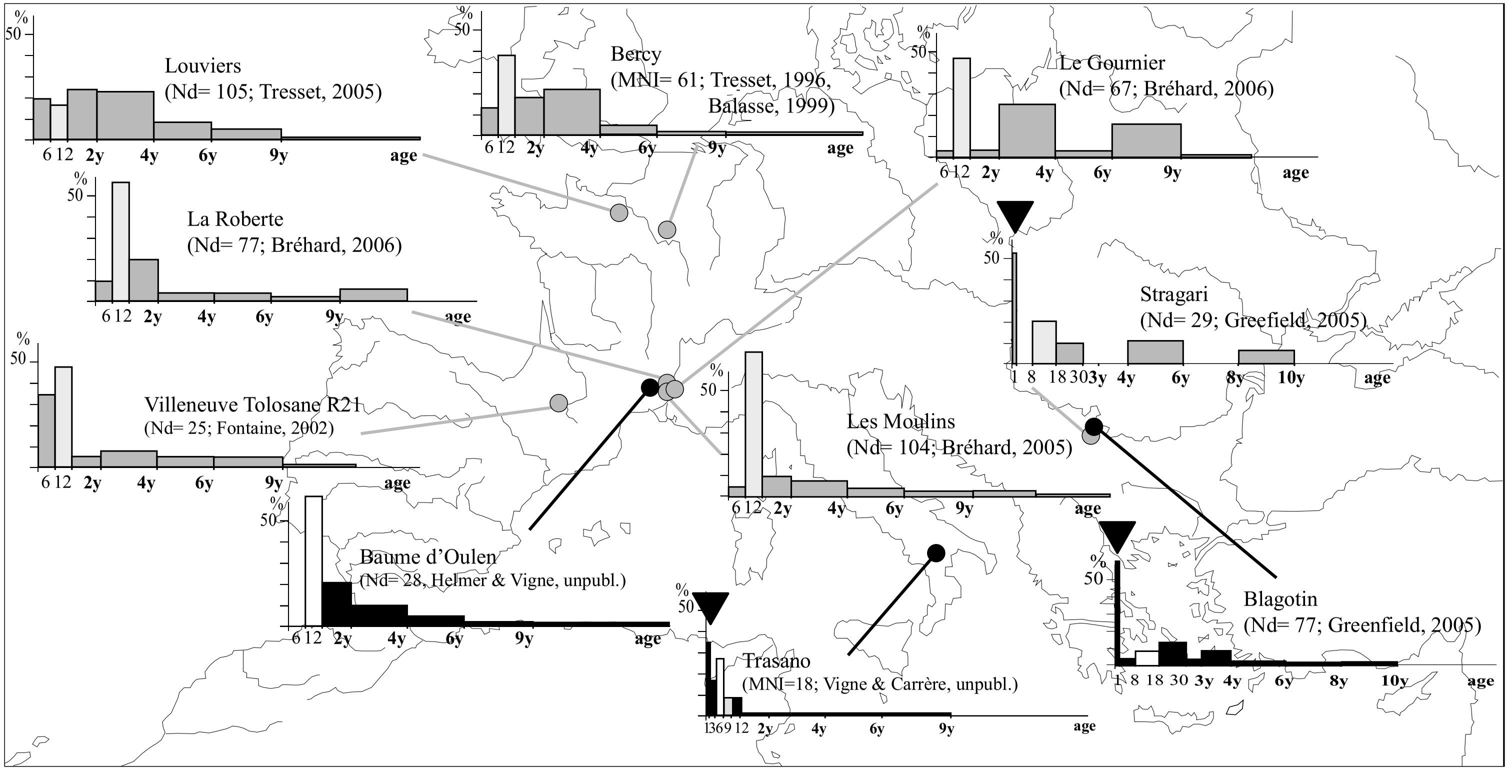


FIG. 11. – Middle Neolithic (grey shade) and 6th millennium Early Neolithic (black and white) cattle harvest profiles in Europe. The medium light grey and white columns, respectively, indicate a probable post-lactation slaughtering peak. The black triangle for Trasano, Stragari and Blagotin indicate the mortality peak for newborns.

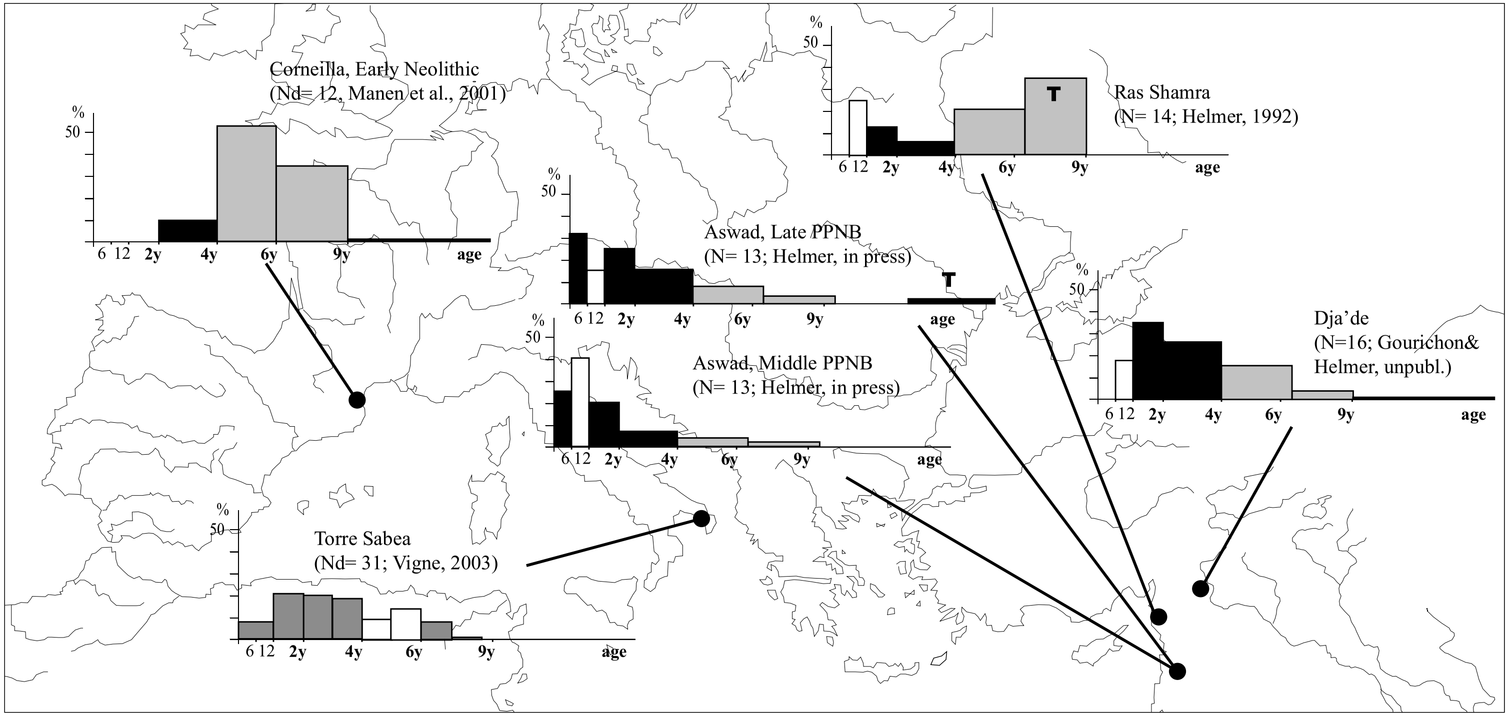


FIG. 12. – Early Neolithic and PPN cattle harvest profiles showing the importance of the slaughtering peaks for animals past usefulness (light grey). T: possible evidence of the use of cattle strength.

which would then reveal that farmers experienced some difficulties in managing their herds, or that they deliberately killed the newborn calves for a special reason.
The natural birth mortality hypothesis is unlikely for Middle Neolithic sites such as Villeneuve-Tolosane or Stragari, where farmers where skilled enough to practice post-lactation slaughtering. To a lesser extent but for the same reason, this is also true for Blagotin and Trasano. Consequently, we should rather consider that this slaughtering of very young calves was related to special practices.
Ritual consumption of newborn calves may be an explanation, especially on large collective sites, the function of which was not only domestic (Halstead 1992). However no archaeological evidence suggests special treatment of the newborn animals on these sites or in a peculiar culture area, and the frequency of the phenomenon leads to consideration of other explanations, especially of a technical nature.
Because this special factor of stimulating the cow's milk release reflex for dairy exploitation is no longer widespread, perhaps we should also consider that Neolithic peoples may have developed other special technical practices which are no longer widely known today. This is not unreasonable, when one considers that some Neolithic groups developed such sophisticated knapping techniques for flint or obsidian that even the best modern specialists struggle to successfully reproduce them, or are not even able to do it as a routine work (*e.g.* PPNA and PPNB bipolar blades). One possibility would be that the Neolithic farmers frequently used techniques which fell into disuse, such as blowing with tubes to stimulate the milk release reflex, or using any kind of substitute for the living calf (see *e.g.* Bernus 1982 for the Tuareg). This would have allowed them to kill the newborn calf and continue milking its mother.
Another possibility would be that farmers kept alive only some of the calves in order to stimulate the cow's lactation, one calf being used to stimulate several cows, but killed the rest very young, in order to reduce the overall consumption of milk by the young. We just presented evidence that early Neolithic people were able to exploit milk from sheep and goats, and that, at least in some cases, they did it by killing the newborn lamb or kid. It is therefore very improbable that they did not try to exploit cattle milk using similar practices. In addition, Columella (VII, 4, 3) wrote:
"*…quippe singuli agni binis nutricibus submittuntur, nec quidquam subtrahi submissis expedit, quo saturior lactis agnos celeriter confirmetur, et parta nutrici consociata minus laboret in educatione foetus sui. Quam ob causam diligenti cura servandum est, ut et suis quotidie matribus, et alienis non amantibus agni subrumentur.* "[3]
This last hypothesis may appear much less realistic for cattle than for sheep and goats, because it is always difficult for a farmer to make a cow adopt a calf which is not hers (Nowak 1998). However, Columella also wrote (VI, 24, 5):
"*Melius etiam in hos usus Altinae vaccae parantur, quos eius regionis incolae Cevas appellant. Eae sunt humilis staturae, lactis abundantes, propter quod remotis earum foetibus, generosum pecus alienis educatur uberibus; vel si hoc praesidium non adest, faba fresa, et vinum recte tolerat, idque praecipue in magnis gregibus fieri oportet.*"[4]
Admittedly, the conservation of one calf for two or more cows is probably much more difficult to

3. "But only one lamb is given to two milking mothers, without depriving it of any milk, so that being satisfied it strengthens quickly, and so that the ewe that has lambed, having another milking mother associated with her, has less difficulty in raising her lamb. Also it is very important that every day the udder of the mother be presented to these lambs, as well as that of the adoptive mother, who not having any maternal affection for the lamb, will not present her udder."
4. Preferred to other cows, concerning the feeding of calves, are those of the Alps, which the inhabitants of those lands called *Cevae*: they are small and abundant in milk, for which reason their calves are removed, so that they may suckle very good calves which are not their own."

do because cows are very sensitive to the smell of their own calf.

However, for all these reasons, we must remain open to the hypothesis that this peak of newborn kill-off may be part of a special Neolithic system for milk exploitation. It should be investigated by obtaining more accurate data about the exact age at death of these very young calves (were all of them already born or did some of them die before or during birth?), and about the diet of the calves which were kept alive in the same herds.

DISCUSSION AND CONCLUSIONS

Biochemical, isotopic and osteoarchaeological data furnish convergent evidence that (i) sheep and goats were exploited for milk as early as the first stages of the Neolithic, in the Near East (Mid-PPNB, early 8th millennium) as well as Mediterranean Europe (mid 6th millennium), and (ii) that cattle were also exploited for their milk using special practices (post-lactation and perhaps some newborn kill-off) during the Early Neolithic in the same regions. In addition, there is some osteoarcheological evidence for the exploitation of sheep hair before the appearance of wool and of the use of cattle strength in the Near East, as early as the Late PPNB.

It is clear for us that "secondary products", especially milk, did not appear secondarily.

THE ROLE OF MILK EXPLOITATION IN THE EARLY STAGES OF ANIMAL DOMESTICATION

This viewpoint sheds new light on the origin of the early domestication of sheep, goats and cattle. Following Poplin (1980) and Gouin (1997, 2002), we must ask the question: Could the domestication of bovids in the Near East have been at least partly motivated by milk exploitation? Several observations suggest a positive answer.

First of all, from a pure intuitive point of view, animal domestication would not have been successful if it had not provided more than hunting. Numerous authors have focussed onto the quantitative aspects of yield, arguing for the better availability of the "walking larder" throughout the year to feed more and more villagers (*e.g.* Clutton-Brock 1989, Harris 1996). If we admit that milk could have been exploited as early as the very beginning of the Neolithic period, we have to widen the focus to include the qualitative advantages of stock keeping: milk procurement is beyond the reach of hunters, but is one of the main innovations in animal domestication.

A more deductive argument can be found in the evolution of the relative proportion of wild and domestic meat between the mid 9th millennium and the end of the 8th millennium, *i.e.* during the PPNB. We have estimated the relation of hunting to husbandry in meat procurement based upon the NISP faunal frequencies for 25 PPN sites in the northern Levant and Cyprus (Fig. 13): five for the 9th millennium (routhly: Early PPNB; NISP= 7,773), six for the first half of the 8th millennium (*i.e.* the Middle PPNB and the Early Cyprus Preceramic Neolithic, CPN; NISP= 16,149) and 14 for the second half of the 8th millennium (NISP= 30,776). Of course, this is a rough approach, since bone weight would have been a better estimator than NISP (Vigne 1992; but weights are not available for all the sites), because all the small vertebrates (fish, birds…) could not be taken into account (because seiving is rare and small vertebrates are not studied for all sites) and because of important ecological and cultural differences between the sites of the eastern Taurus, the Euphrates valley and the Damascus area. In addition, the relative proportions of wild and domestic animals for cattle (aurochs), sheep (mouflon), goats (bezoar goat) and pigs (wild boar) remain unclear for most of the sites. Except for Cyprus, for which we have some estimations (Vigne *et al.* 2003), we decided to include all the NISP of these species within the contribution of the domestic species, which produces an over-evaluation, especially for the earliest periods.

The result is that the average contribution of hunting to meat procurement is highly dominant (80% of the NISP) and remained dominant (55%) during the first half of the 8th millennium.

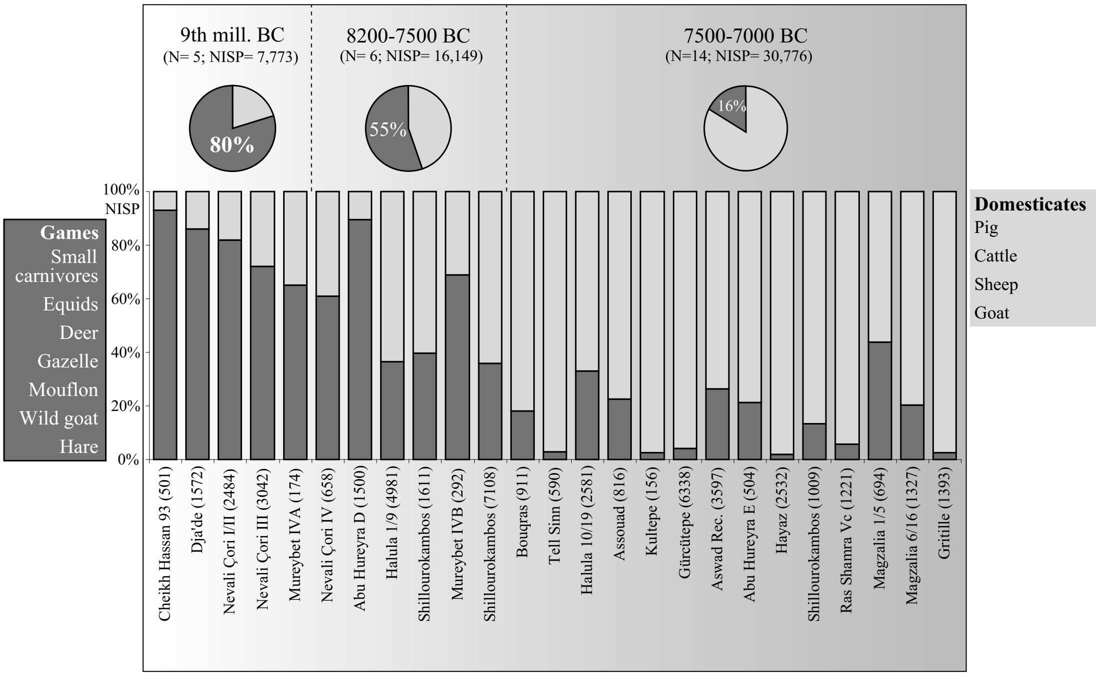


FIG. 13. – Evolution of the proportion of the number of identified specimens (NISP) of mammals in 25 chrono-cultural phases of the Early, Middle and Late PPNB in the northern Levant.

Farming began to provide most of the meat only ca. 7600-7500 BC, *i.e.* more than 10 centuries after the beginning of animal domestication. We propose that, during this time, hunting continued to provide meat as it had for millennia, while domestic animals were at least partly exploited for their "secondary products", especially milk, which hunting could not provide. This would explain how these early Neolithic societies could have had a dairy economy in spite of low milk yield, since hunting supplied important animal protein. This would also explain why some of these societies maintained a high level of hunting during the first stages of the Neolithic period (see for ex. Tresset & Vigne 2001).

Thus it must be considered that the domestication of sheep, goats and cattle in the Near East could have been at least partly motivated by milk procurement. However, we must be careful not to fall into a mechanistic explanation. If early domestic animals were not mainly intended for meat supply in the Near East during the eight millennia of the Early and Middle PPNB, they were probably not only used for milk procurement either. We have also to take into consideration, in different proportions according to time and place, (1) the "buffering effect" (Halstead & O'Shea 1989) of the "walking larders" during the seasons when the supply of wild animals was less abundant or more difficult to obtain, (2) the other supplies that could only have been obtained in large quantities by hunting (hair), (3) the animal strength which now appears to have been used as early as the beginning of the Middle PPNB (Aswad, Damascus) and (4) the important social prestige that may have been attached to "animal ownership" or even "animal appropriation".

In this light, the late PPNB, starting in the mid-eighth millennium BC, and the subsequent spread of the Neolithic way of life towards Europe and the more eastern areas of Asia, stands out as a new stage in the Neolithic process. At that time, people obtained most of their meat from stock-keeping and deeply modified the morphology of the domesticates, giving animal husbandry a stable status (contrary to the previous 'unstable status'; Vigne *et al.* 2003) and breaking the gene flows between wild and domestic populations. In short, they shifted at that time from "stock-keeping hunter-cultivators" to true Neolithic farmers. In the areas where the Neolithic new way of life was to be introduced towards the west or the east, beginning in the Near East, people could have recomposed the different components of the Neolithic package, in such a way that, here and there, many centuries later, we may again find Neolithic "hunter-cultivators" or even "stock-keeping hunters", as we did at Roucadour, in southern France for the 6th and 5th millennia (Lesur *et al.* 2001, Tresset & Vigne 2007, Vigne 2007, in press).

This scenario lends a special anthropological interest to these Near Eastern "stock-keeping hunters-cultivators" who invented animal domestication between the Early PPNB and the early Middle PPNB (mid 8th and mid 7th millennia), and who may be considered to be exceptional societies which have no modern parallel.

The so called "secondary products" revolution

This revised interpretation of the early domestication of most of the Neolithic ungulate species in the earliest cradle of Old World Neolithisation leads us to revisit the nature and the historical importance of the "secondary products" revolution. Of course, it does not reduce the historical importance of the invention of the plough, the wheel or the domestic horse, neither does it deny the historical, cultural, economic and environmental importance of these true innovations, as already pointed out by Sherratt and other authors. But it involves several new perspectives.

According to Leroi-Gourhan (1973: 94: "*…tout peuple connu est complètement humain et […] toutes les possibilités techniques élémentaires sont dans l'homme.*"[5]), we have to restore to favour the technical skills of the last early Neolithic hunters (not yet true farmers but only "stock-keeping hunters-cultivators"). These technical skills, as well as high-level social organisation and the profound oral transmission of knowledge that these skills require, are obvious in other respects during the Near Eastern PPNB, *e.g.* for bipolar lithic knapping (Abbès 2003) and the existence of extraordinary buildings (Jerf El Ahmar, Stordeur *et al.* 2000; Göbekli Tepe, Peters & Schmidt 2004). This supports the reactions of Chapman (1992) to the "'secondary products' revolution", when he emphasized the much more sophisticated behaviour and structures of Neolithic societies. In its first proposal Sherratt's theory strengthened the implicit paradigm that there was a prehistoric Neolithic, *i.e.* without writing, without cities and without any abilities other than killing animals for their meat exactly as did hunters-gatherers, and a 'Post-Neolithic' with writing, cities, social hierachies, etc., in short, "civilization". Only these "civilized people" would have been able to draw (without any salvage murdering!) from animals what their "hunter-gatherer ancestors" could not imagine, through the millennia, that it was possible to do. We feel that the idea of the "secondary products' revolution" is somewhat laced with a kind of ethnocentrism that tends to underevaluate the potentialities of other peoples, in space and here, through time. The data that we have brought together here suggest that considering early Neolithic "stock-keeping hunters" of the Near East or Mediterranean areas to be people of low technical skill is clearly a misinterpretation.

A reappraisal of the concepts and terms of "primary products" and "secondary products" is therefore necessary. As we pointed out in the introduction, this typology is disconnected from

5. "All known peoples are fully human and [...] all the elementary technical possibilities are present in man."

any anthropological frame. We have presented above different kinds of evidence, that the exploitation of milk, probably hair and the strength of early domestic animals did not occur in a secondary way in Neolithic historical progress, and that milk exploitation at least could have played an important role at the very start of Early Neolithic animal domestication, at least for some species and in the Near East. Thus, the so-called "secondary products" are not secondary, from either the historical or the processual point of view. In addition, we feel that, even if this is not their explicit definition, these terms implicitly convey the idea that technical evolution is linear through time, and imply an ethnocentric underestimation of the last hunters and of early Neolithic people, which we have stated to be clear misinterpretations. Thus we propose replacing "primary products" with "final products" (as already suggested by Clason, in Greenfield 1998), because they are obtained at the final stage of the "chaîne opératoire", and "secondary products" with "ante-mortem" or better "life-time" products.

Although the proposals that we have presented in this paper may appear to make sense as a whole, they are only hypotheses. We wish to stimulate and contribute to new archaeological and archaeozoological research in order to test these hypotheses, at more precise geographical and chrono-cultural scales as the very large ones that we adopted here. And we wish to attempt to change the opinions of those numerous non-specialists of the Neolithic period, who continue to believe that civilisation in the Old World began with the invention of writing.

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