

THE INTERACTION BETWEEN BIOLOGICAL AND TECHNOLOGICAL CHANGE DURING THE DEVELOPMENT OF DIFFERENT FLEECE TYPES IN SHEEP

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Summary

The Neolithic feral Mouflon of Corsica shows that it took several thousand years after domestication for a fleece to develop. Although wool may first have been used as felt, suggested by the natural felting of a moulting coat, the earliest remains are of Bronze Age cloth that indicates the combing of underwool from the outer hair before the full development of the first (Hairy-medium) fleece. The later, Generalised-medium, fleeces were plucked. Twisted strands of wool formed when a sheep rubs a moulting fleece could have led to spinning, Hairy-medium fleeces giving worsted yarns and Generalised-medium fleeces, woollens. Breeding for continuous wool growth could not begin before the development of shears in the Iron Age and it led to a new, true Hairy type of fleece. This was also when breeding for white wool started along with the development of dyes.

Résumé

Interaction entre l'évolution biologique et les changements technologiques lors de l'émergence des différents types de toison chez le Mouton.

Comme l'illustre le Mouflon marron néolithique de Corse, il aura fallu plusieurs millénaires après la domestication pour qu'apparaisse un toison laineuse. Bien que la laine ait probablement été d'abord utilisée sous forme de feutre, comme le suggère le feutrage naturel des toisons de mue, les premiers témoignages sont des vêtements de l'Age de Bronze qui démontrent le cardage de la laine cachée sous le pelage extérieur avant même que n'apparaisse le type le plus primitif de toison (Hairy-medium). Ces dernières (Generalised-medium) étaient récoltées par arrachage à la main. Les brins de laine tressés qui se forment lorsque les moutons frottent leur toison en mue peuvent être à l'origine de l'idée de filer la laine, les toisons Hairy-medium donnant un fil raide, alors que les toisons Generalised-medium donnent un fil laineux. Les croisements pour l'amélioration ultérieure de la laine ne pouvaient pas débiter avant le développement de la tonte, à l'Age du Fer ; ils ont conduit à un nouveau type de toison, réellement "hairy" cette fois. C'est également à ce moment que débutèrent les sélections pour obtenir de la laine blanche, alors que les teintures se développaient.

Key Words

Fleece, Shearing, Sheep, Textiles, Dyes, Wool

Mots clés

Tonte, Mouton, Textiles, Teintures, Laine

Introduction

The domestication of sheep, and the subsequent development of a range of fleece types now having a variety of uses, were complex biological processes that are still imperfectly understood. The problems therefore are as biological as they are archaeological, but just as biological studies have added to archaeological knowledge, so archaeological evidence is throwing light on biological changes. Another aspect, which forms the theme of this paper, is the apparent existence of

interactions between biological and technological change e.g. breeding for continuous wool growth could not take place before the invention of iron shears. The main sources of the evidence used are wool remains, mostly from textiles, and fleece details in ancient representations of sheep, as well as of surviving primitive domestic breeds. In outline, the major changes in the coat have been : (a) the development of a fleece through the gradual thinning of the coarse kemp-hairs of the outer coat of the wild ancestor ; (b) the loss of the natural colour of the wild sheep ; and (c) the change from a moulting coat to a

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fleece with continuous growth (RYDER, 1983a). The changes will be discussed within the framework of the Neolithic - Bronze Age - Iron Age terminology⁽¹⁾.

Domestication

Since I wish to concentrate on changes after domestication, I will say little about this complex biological process, which was discussed in detail by RYDER (1983a). Once the unconscious (ecological) nature and essential gradualness of domestication is realised, the question why animals were domesticated becomes irrelevant. Sheep were almost certainly not domesticated for their wool since the wool of the wild ancestor is obscured beneath the outer kemp-hairs and the coat is little different from that of deer and goats.

The first domestic sheep of the Neolithic period, are likely to have provided skins for clothing as well as meat. But domestic animals in providing food reserves and prestige objects soon became more valuable alive than dead, and this could have stimulated the development of alternative sources of food in the form of blood and milk (fig.1). A shortage of skins could have provided a similar stimulus to seek an alternative to skins for clothing, in the form of wool, which, as with milk, archaeologists now call a Secondary Neolithic Product (SHERRATT, 1981). The first use of wool was almost certainly as a felt.

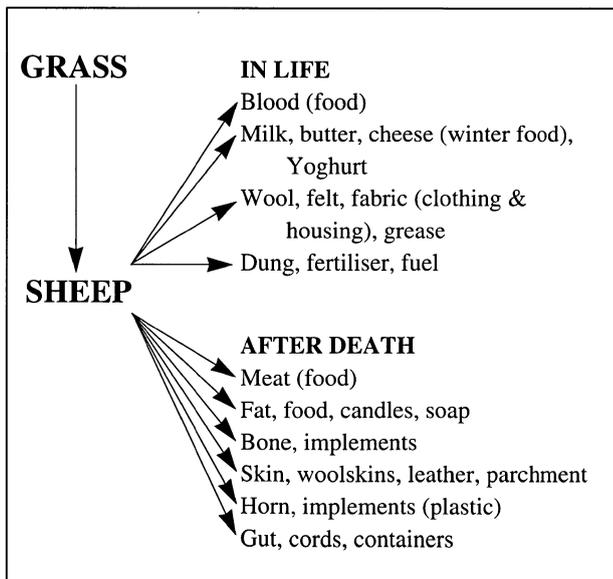


Fig. 1 : Summary of sheep products, those at the top being obtained from the living animal after domestication. (From RYDER, 1983a p. 713).

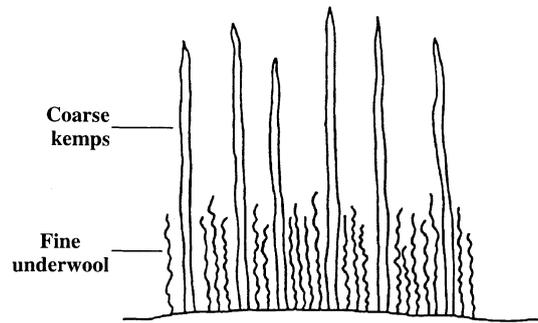


Fig. 2 : Double-coat structure of wild sheep in which very coarse, outer kemp-hairs obscure very fine underwool. (From RYDER, 1983a p. 16).

The coat of Neolithic sheep

It has long been realised that the coat of the first domestic sheep would have been the same as that of the wild ancestor. This comprises an outer coat of very coarse, bristly kemp-hairs, which obscure very fine underwool (fig. 2). What has more recently become obvious is the time taken for a fleece to develop. The crucial evidence for this comes from the "wild" Mouflon sheep of Corsica and Sardinia. Since sheep could not have reached these islands other than through human influence, it is now realised that they are not truly wild, but feral descendants of domestic sheep introduced by Neolithic settlers about 5500 b.c. (POPLIN, 1979). Because these have a coat that is apparently no different from that of other wild sheep, such as the Bighorn of North America (RYDER, 1958), which was never domesticated, it appears that little or no change took place during several thousand years that elapsed between domestication and their introduction to these islands. The "wild" Mouflon of Cyprus must also be a feral domesticate (DAVIS, 1990).

RYDER (1984a) identified this type of "hair" coat among remains of skin from domestic sheep in Sudan dating about 2000 b.c. Associated textile remains were of flax, but interestingly some of the skin remains had the first indications of a fleece (see section "Illustrations of fleeces" below). The term "hair" used in agriculture for this type of sheep is confusing since the hairy fibres of the outer coat are kemps and not hairs. A more explicit if inelegant term is "non-fleeced". WALTON (1988) reported on eight samples of non-fleeced coat in sheepskin capes of the Danish pre-Roman Iron Age.

Similar remains of skin from survivals of Neolithic sheep were found on the Iron Age site of Hallstatt in Austria (RYDER, 1990a, 1992) These had a range of colours like the non-fleeced sheep of ancient Egypt, and some had the colour pattern of the Corsican Mouflon. This means that not only did a Neolithic (or feral), non-fleeced sheep persist until the Iron Age, but that some did so with a Mouflon colour pattern.

The Neolithic type of coat still survives in the kempy, so-called "hair" sheep of tropical Africa and India. As a result of domestication these breeds have black sheep and white sheep in addition to the brown of the wild ancestor (the main colour in the Mouflon). Black, and more rarely white, variants occur in wild ruminants and domestication allowed such mutants not only to survive, but eventually to multiply when human selective breeding was applied (RYDER, 1983a).

Skin-working tools are a feature of the Neolithic period and these decline later with the development of textile crafts seen as an increase in the number of spindle whorls and loom weights. But there is no evidence for either fleeced sheep or wool cloth before the Bronze Age. In my experience, textile remains that have been claimed to be Neolithic wool have turned out to be either made from flax, (e.g. the cloth from Catal Hüyük in Turkey, RYDER, 1965) or if wool, have not been as old as the Neolithic. The existence of late Neolithic whorls and weights therefore indicates either that flax was spun before wool, or that a fleece was developed (or underwool used) before the end of the Neolithic period. Bone remains indicate a change in sheep husbandry between the Neolithic and the Bronze Age which has been interpreted as indicating a greater emphasis on secondary products including wool (GREENFIELD, 1988).

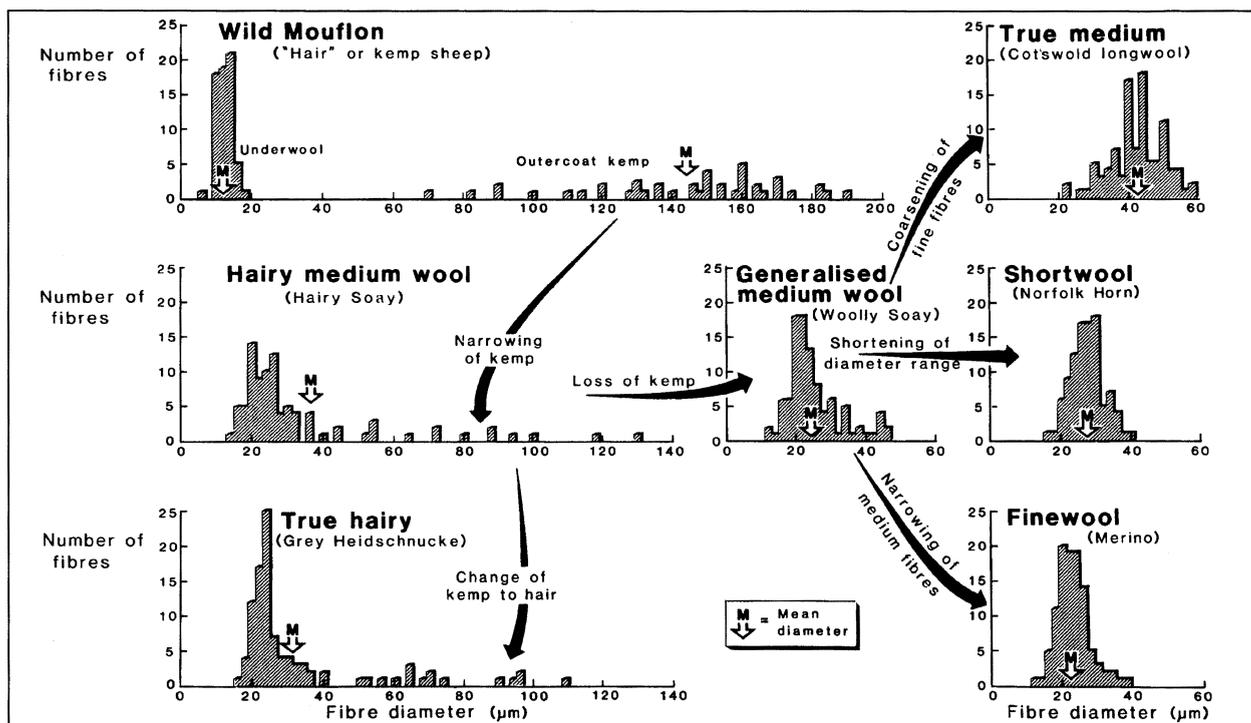


Fig. 3 : Changes in the coat during fleece evolution. Each diagram in the form of a histogram shows the distribution of fibre diameter (based on the measurement of 100 fibres), which defines fleece type. The arrows indicate the changes that occurred when breeding caused one type of fleece to change into another. The main change has been a progressive narrowing of the outercoat kemp-hairs. These became finer as the coat of the Neolithic sheep (top left) changed into the first (Hairy-medium) fleece of the Bronze Age. Since this diagram was drawn, as shown in Table 1, evidence has been obtained for early intermediate stages with only kemp and fine wool - the Hairy-medium fleece has fibres of medium diameter (derived from the outer coat) as well as kemp and fine wool. The remaining finer kemps then changed into medium fibres to give the Generalised-medium fleece. Further narrowing changed them into the fine fibres of the Fine wool (bottom right). Other changes resulted in the Semi-fine (shortwool) and the Medium-wool (later seen in the longwool). The last three (modern) fleece types first appeared in the Iron Age and became more common during the Roman period. The Hairy type (bottom left) also appeared during the Iron Age when short kemps changed into long hairs. The breeds named are the examples used to illustrate the different fleece types. (From RYDER, 1983a p. 46). (One micron, μ , = 0.001 mm).

Wool Felt

Before discussing the way in which a fleece development, I will consider felt, which can be made from the coat of a non-fleeced sheep, and which was almost certainly the earliest wool fabric (RYDER, 1983a). Ethnographic studies of felt clothing suggest that earliest designs were based on the style of earlier skin garments. There are suggestions of wool felt at Catal Hüyük (6500 b.c.), but actual remains date no earlier than Pazirik (500 b.c.) (RYDER, 1990b). Felting is a property of wool that depends on the scaly fibre surface. This allows the fibres to move in one direction only when rubbed so that they become irreversibly tangled. The felting process is speeded by warmth and wetness. It was probably discovered by the observation of the natural felting of a moulting coat on a sheep's back. I have observed that in Mouflon and hairy Soay sheep, the moulting underwool frequently becomes entangled in the outer hair and felts together before falling from the animal in felted masses.

The development of a fleece - Bronze Age wool

The main change involved in the development of a fleece was the narrowing (thinning) of the outer coat kemp-hairs (RYDER, 1983a ; 1987a). Since the outer coat of Mouflon sheep is much finer and softer than that of red deer, for instance, (RYDER and KAY, 1973), it may be that unconscious selective breeding for a softer (and therefore finer) coat began while sheepskins were still being worn for clothing. As the outer coat became less coarse, the underwool became less fine, changing from the mean fibre diameter of 15 microns (one micron = 0.001mm) in wild sheep, to 20 microns, which has been the typical value for fine wool ever since (fig.3). The evolutionary changes involved in the breeding development of the main fleece types are shown in figure 3. The different fleece types are illustrated by typical fibre diameter distributions in the form of histograms. The first true fleece was the Hairy-medium type, which developed by a narrowing of the outer-coat kemps. This type is characterised by a skewed fibre diameter distribution in which most of the fibres are fine and there are a few hairy fibres. Further narrowing of these hairy fibres (fine kemps) changed them into wool fibres of medium diameter and produced the Generalised-medium type of fleece. Some of the Soay sheep on St Kilda have a Hairy-medium fleece, while others have Generalised-medium wool. Both

retain the brown upper parts and white belly of the wild ancestor as well as a primitive short tail. The same two types of fleece are found in Danish Bronze Age wool, and this, together with its brown colour, supports evidence from bone remains that Soay sheep are survivors from the Bronze Age (RYDER, 1969 ; RYDER, 1983b).

The first stages - "intermediate" fleeces

The major advance in recent years has been not only the discovery of survivals of Neolithic sheep into European Iron Age (above), but of textile remains giving hints of a fleece intermediate between the coat of Neolithic sheep and a Hairy-medium fleece (table 1). An intermediate stage can perhaps be seen in the wool from some of the earliest textiles found in Denmark (RYDER, 1988). In the 1930s this was thought to have been mixed with deer hair, but it is now realised that the "deer hairs" are really sheep kemps.

The first Bronze Age sample measured, although described as a Hairy-medium wool, had an unusually high proportion of fine fibres (RYDER, 1969). This implies harvesting of the fine fibres by combing (see below), but with little or no removal of hairs afterwards. A further indication of an intermediate type was obtained by RYDER, 1983b in that three of 24 Bronze Age wools measured had only kemps and fine wool, i.e. none of the medium fibres found in Hairy-medium fleeces.

	Neolithic	Intermediate	Bronze Age	Iron Age
Coat	coarse kemp 15 μ wool	1. fine kemp & 15 μ wool 2. fine kemp & 20 μ wool	Hairy-med. & Generalised- medium	same
Colour	brown	brown	brown	brown, black, white, grey.
Present breeds	Tropical "hair"	none known	hairy & woolly Soay	hairy & woolly Orkney
Harvest	comb	comb	comb HM pluck GM	shear
Fabric	? felt	? felt	HM woollen GM worsted	same

Table 1 : Summary of fleece changes in sheep (see also fig. 3).

Another group of 34 (notably early) Danish Bronze Age wools described by RYDER (1988) had seven with no hairy fibres, and wool that was finer than in any previous domestic sheep measured. This wool appears to have been combed from the coat of a sheep more primitive than the Hairy-medium type if not from the Neolithic type itself. The amazing lack of a single hairy fibre in any of these samples could be due to their removal by the fingers after harvesting (see section on harvesting).

Mean fibres diameters as fine as the above are usual in goat underwool, which is used as cashmere fibre. This led me to use Scanning Electron Micrographs of the surface scale patterns to investigate the possibility that the fibres were from goats rather than sheep, and indeed a few fibres were from goats (RYDER, 1988). But there was no suggestion that goat fibres were used as well as wool, either separately or as a mixture. The majority of the fibres were wool from sheep and the few fibres of goat underwool could have got into the sheep's wool as contaminants from goats grazed with sheep.

Three other examples of "Neolithic wool" are as follows. First, the similarity to "Neolithic underwool" of some fine Scythian wool of the fifth century b.c. from the Crimea was noted by RYDER and HEDGES (1973) and this was confirmed in a re-assessment by RYDER (1989) during the examination of some Hellenistic wool about 2000 years old from Enkomi in Cyprus, which provides the second example. The third example was one of 13 yarns in another collection of Scythian wool from Pazirik (RYDER, 1990b).

Illustrations of fleeces

In Mesopotamia there are pictorial representations of sheep dated about 3000 b.c. in which the coat is shown smooth or by straight streaks. I interpret this as the non-fleeced Neolithic type. This was also the first type depicted in Egypt. From the Early Dynastic period of Sumer sheep are depicted with the clear wool staples (locks) of a fleeced sheep (RYDER, 1983a, 1984b).

The wool staples of sheep fleeces tend to have a broad base and a pointed tip. The tip is formed by the longest and coarsest fibres, and the base is filled out by the more numerous shorter and finer fibres. The structure and pyramidal shape are most marked in hairy fleeces. An early representation of a sheep dated sixth millenium b.c. found at Sarab in Iran has the first hint of a fleece. Despite the crude outline of the animal, the wool is depicted by a series of V-shaped markings that appear to indicate the staples of a Hairy-medium fleece (fig. 4). Fleeces are not depicted in Egypt until the first millenium

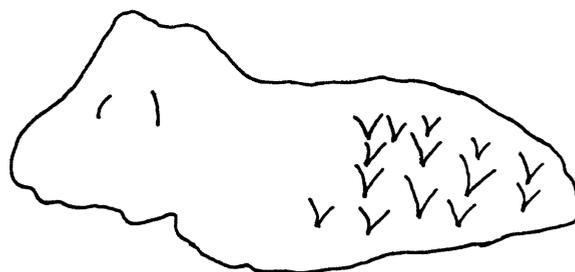


Fig. 4 : Clay sheep figurine from Sarab, Iran, C. 5000 b.c. showing V-shaped wool staples, which appear to be of hairy medium type. (From RYDER, 1983a p. 52).

b.c. and again the staples have a V shape suggesting a Hairy-medium fleece. One or two Hairy-medium fleeces were found among mainly non-fleeced skins at Kerma, Sudan dating about 2000 b.c. (RYDER, 1984a).

As fleeces became finer, the fibre length as well as the diameter became more uniform and so the wool staples tend to have a straight end and to be "blocky" rather than "tippy". Such staples are found in modern Medium, Semi-fine and Fine wools. After 500 b.c. fleece depictions from Persia, Greece and Rome become sufficiently clear to indicate different fleece types and sometimes the age of the animal (RYDER, 1983a, 1984b).

Wool harvesting

The fleece of the Bronze Age Soay sheep that survive on St Kilda moults naturally each spring. Before the shearing of sheep was possible (see below) moulting fleeces were harvested by plucking, a method of obtaining wool that persisted in such places as Shetland until recent times. Textile remains often have fibres with the brush end that is formed when fibres shed. Since the hairy fibres of Hairy-medium fleeces tend to shed later than the wool, plucking allows one to obtain wool that contains fewer hairs than shorn wool.

This explains why some Bronze Age wools contain more finer fibres and fewer hairy fibres than expected. It also implies the combing of the wool from the hair on the animal. But combing would only be necessary with hairy fleeces. Generalised-medium fleeces can be plucked and this is what was done on Shetland without the help of a comb.

From the fact that the Sumerian word for "shear" is indicated by the picture of a comb, MELENA (1987)

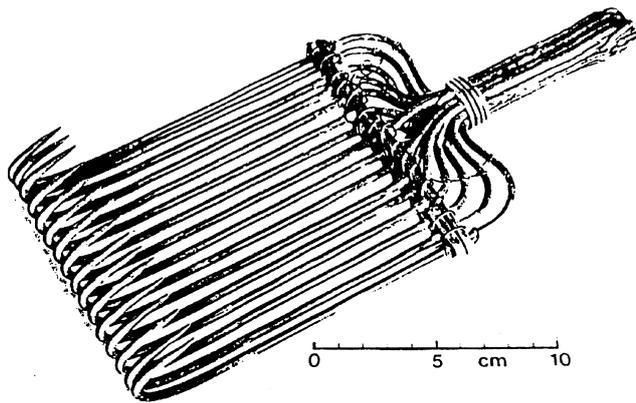


Fig. 5 : The traditional iron comb used to harvest cashmere underwool from moulting goats in China. (From RYDER, 1987b).

concluded that combs had been used to harvest wool before the development of shears, which are first recorded in a Neo Babylonian text of about 500 b.c. Combing is the way that cashmere is harvested from goats in China (LI JIAN-PING, 1988) where hairy sheep, too, are combed to obtain the finer wool. The combs are small rakes with a short handle and are either made of wood or iron, the latter having hooked and pointed teeth (fig.5). The bone "weaving combs" that have long been thought to be unsuitable for this purpose because of their concave section (ROTH, 1915), are therefore not appropriate for use in wool harvesting either.

Although I worked with goats as early as 1961, it was not until spring 1984 after I had started working on cashmere production that I actually combed the underwool from British feral goats. Combing is relatively easy, but it is impossible to obtain the underwool completely free from hairy fibres. This makes it more surprising that some Bronze Age wool (above) contained no hairy fibres at all. The answer comes from MOOCROFT and TREBICK (1841) who described how women in Kashmir removed hair from cashmere fibre entirely with the fingers, the time taken to de-hair less than 60 g of fibre being two hours. It is therefore possible that kemp-hair was removed from Bronze Age wool in the same way.

The pre-requisites for combing are that moulting of the hairy fibres and wool is asynchronous, and that there is a large difference in diameter between them.

The latter means that the more primitive the fleece, e.g. the early Bronze Age wool (above), the easier it is to comb. The rareness of perfect asynchrony, however, means that modern, raw cashmere virtually always contains some hair. In fact, the Mouflon sheep I worked with during the 1960s shed their kemp-hairs at the same time as the underwool so that it was impossible to separate the two. This emphasises that all animals vary, and indeed without such variation selective breeding would have been impossible.

Iron Age wool

Textile remains from the Iron Age show a predominance of the same, primitive, Hairy-medium and Generalised-medium fleeces that appeared in the Bronze Age, but there is a greater range of natural colour. In addition to the brown of Bronze Age wool there is black (both of which have 100% pigmented fibres), grey (a mixture of pigmented and white fibres) and white (no coloured fibres). This range, first observed in the local wool from Vindolanda (40% white wools, RYDER, 1983a p. 180) has been confirmed at Hallstatt (45% white, RYDER, 1990a). WALTON (1988) noted 90% white in Norwegian, and 95% in Danish, Iron Age wools. Compared with the unique Bronze Age Soay, there are more survivals of this Iron Age sheep in scattered pockets throughout Europe (RYDER, 1979), the British examples being the Orkney and Shetland breeds. These are characterised by a predominance of grey animals and a tendency to moult, as in the Soay, with which they share a primitive short tail. But, of relevance to studies of bone remains, unlike the Soay, only the rams are horned.

A new, additional type of fleece, the true Hairy type, appeared for the first time in the Iron Age. This evolved by a change of many of the short, shedding kemps of the Hairy-medium fleece into long, continuously-growing heterotype hairs (fig. 3, bottom left). Hairs are intermediate between kemp and wool : they are thick and kemp-like in summer, but thinner in winter when they appear like wool fibres. Whereas kemp-hairs cease to grow in winter before moulting in spring, heterotype hairs merely thin down and continue to grow.

The origin of hairs was associated with the change to continuous growth. Moulting is a disadvantage in leading to loss of wool by the sheep keeper. Some sheep moult prematurely before the normal time for plucking, while others are not ready for plucking or combing until later. There would be a wish therefore to selectively breed against moulting, but this could not begin until an

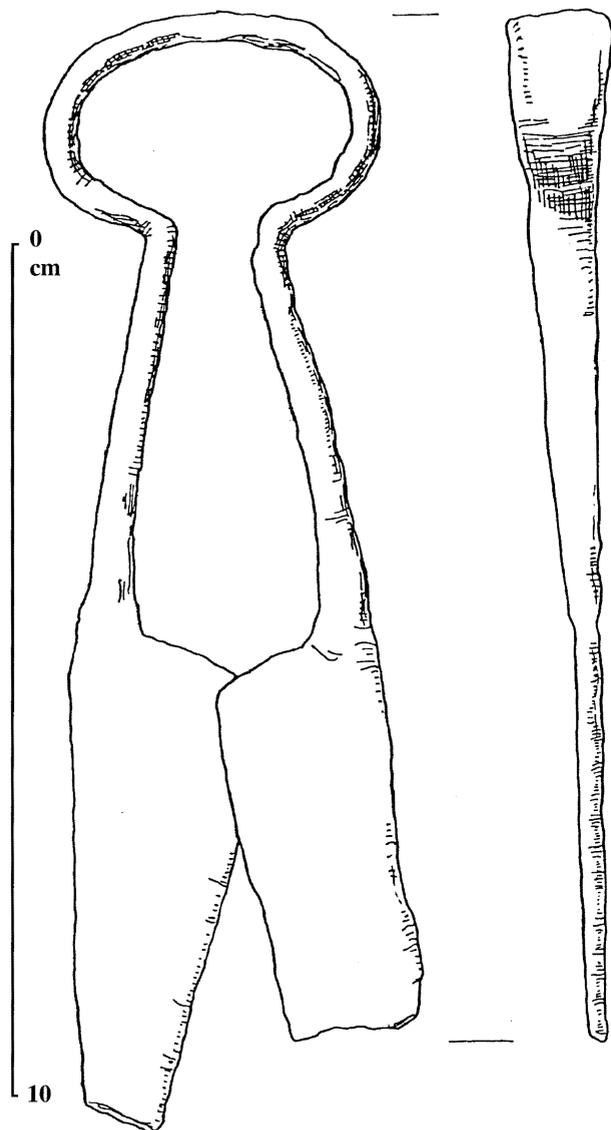


Fig. 6 : Iron sheep shears from a Roman site in Britain. Having soon evolved to their optimum design, shears have changed little in 2000 to 3000 years. (From RYDER, 1983a p. 697).

alternative method of removing the fleece had become available with the invention of shears during the Iron Age (in Anatolia about 1000 b.c.).

Since shears are two knives working against each other, they may have been preceded by a knife, and not

only are sheep still shorn with a knife in Nepal, but last century when the St Kildan islanders acquired sheep that did not moult, they initially used a knife to remove the fleece. Shears large enough to shear a sheep are found from the late Iron Age on in Europe. The iron bow linking the blades provides a spring in a design that has changed little in over 2000 years (fig. 6).

It is remarkable that this technological advance preceded the biological change to continuous wool growth. Another technological advance associated with a biological change is the development of dyes. Although white, Neolithic "hair" sheep were perhaps kept as a novelty, the real stimulus to breed sheep with white wool came not only after the evolution of a fleece, but after the development of dyes. At the same time, wools of different natural colour were woven together until well after the Middle Ages.

Nearly all wool remains from the Near East during the first millennium b.c. lack natural pigmentation and have been dyed. Here the Phoenicians extracted Tyrian purple from *Murex* shellfish. But if shell mounds are features of Phoenician sites, evidence should be sought among Iron Age pollen in Europe of an increase in dye plants as an indication of an increase in the number of white sheep.

Mutations in Icelandic sheep suggest the sequence of colour change. (a) The wild pattern white belly has been observed to mutate to all white. This explains the rarity of sheep with a white belly subsequent to the Bronze Age type. (b) White has been observed to mutate to self colour (giving all brown or all black animals). This explains the occurrence of some white wool in Bronze Age cloth and also the brown and black sheep in the Soay breed. (c) Self colour has been observed to mutate to grey (a mixture of coloured and white fibres). This explains the lack of grey in the Soay and its predominance in Iron Age wool (RYDER, 1990c).

The breeding of white sheep by selecting piebald animals with greater and greater areas of white (as proposed by experimental archaeology at Butser) cannot have been the sole way in which this occurred. Since spotted animals are recessive this would have resulted in recessive white breeds, which do not exist. Dominant white sheep must have been selectively bred. But since coloured individuals of modern white breeds are often spotted, spotting must have been unconsciously selected at the same time. Because the white wool of spotted sheep is often finer than the coloured wool, selection for spotting could have also tended to make the fleece finer (RYDER, 1990c).

Textile technology

How to weave plant stems into basketry was known before domestication. The Neolithic advance leading to cloth making was the spinning of fibres into yarns through the discovery that twist imparts strength to a strand of fibres. An untwisted strand lacks the cohesion and strength needed for weaving, but the insertion of a few twists to produce a yarn gives remarkable strength. As with the discovery of felt, so observations of fleeces could have inspired people familiar with basketry to produce yarns. Masses of moulting wool instead of felting are often rubbed by the sheep into long, twisted strands resembling yarns. I collected twenty such coarse "yarns" from a moulting Mouflon and wove them into a rudimentary piece of cloth (RYDER, 1983a : 136).

Wool would originally have been spun direct from fleece, and since the hairs of Hairy-medium fleeces keep the wool fibres parallel (particularly after shearing), the first yarns produced would have been worsteds, a type of yarn with parallel fibres that is supposed not to have been developed until the Middle Ages. The only preparation likely is combing to improve the parallel arrangement, which is another use for "weaving" combs. As wool became finer with the change from Hairy-medium to Generalised-medium fleeces, it would have become more difficult to comb, as with the fleece of the surviving woolly Soay. The yarns produced would therefore have been woollens in which the fibres are randomly arranged. Preparation for wool spinning involves carding, but there is no evidence of hand cards (boards set with wires) before the Middle Ages. However, the name "card" comes from the Latin *carduus*, a thistle, and this suggests that wool was originally carded with thistle heads or teasels.

The final changes to modern fleece types

Figure 3 shows that the Generalised-medium fleece lies in a central position linking the more primitive hairy fleeces to the left with the modern fleece types to the right, which have a symmetrical distribution of fibre diameter. The first fleece changes involved a reduction in the diameter of the outer-coat hairs. If this trend had continued with a further narrowing of the medium fibres of the Generalised-medium type to make them into fine fibres, then the diameter distribution of the Fine type would have been produced (fig. 3 bottom right). If instead the Fine fibres had been bred coarser, changing them into medium fibres, then the Medium diameter distribution (seen today in the longwool) would have been obtained (top right). Thirdly, if the range of fibre diameter had become shortened, the distribution produced would have been that of the Semi-fine fleece, seen today in the shortwool (centre right).

Until recently it was thought that these modern fleeces first appeared in Roman times, but the Medium and Semi-fine types have now been found (in small numbers) in Asiatic and European Iron Age textiles (RYDER 1990a et b) at a time when the Fine wool was emerging in the Near East (RYDER, 1983a). The Hairy-medium and Generalised-medium types predominated in northern Europe until after the Middle Ages when Medium and Semi-fine fleeces became important. The Fine wool was important in southern Europe in classical times and later developed into the Merino of Spain. The retention of a kempy coat in tropical non-fleeced sheep can be interpreted as being due to the lack of a stimulus to breed a woolly fleece for clothing in a hot climate. In fact, in some tropical breeds the underwool has actually become reduced, presumably as an adaptation to heat loss brought about by natural selection (RYDER and STEPHENSON, 1968).

⁽¹⁾ Wool fibre terminology and definitions : Mammals have hair, and the wool of sheep is a kind of hair. But wool biologists divide "wool" into three types of fibre : short, thick kemps ; long, less-coarse hairs ; and finer, true wool (which itself can be coarse, medium or fine). Kemp and hair are collectively referred to as "hairy fibres". The coat of wild and Neolithic sheep had only very coarse kemp and very fine wool. Such "hair" sheep are better described as "non-fleeced" to distinguish them from woolly, fleeced sheep. Fleeces are primarily composed of wool, but many have varying, smaller proportions of kemp and hair depending on the fleece type. Wool yarns (spun threads) are either "worsted" spun, in which before spinning the fibres are combed parallel, or "woollen" spun, where the fibres are carded to give a random arrangement.

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