DETERMINING PREHISTORIC SKIN PROCESSING TECHNOLOGIES

The macro and microscopic characteristics of experimental samples

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Preface

My interest in tanning and my eventual path towards this research began at thirteen years old when, after a number of rather smelly unsuccessful attempts, I finally tanned my first deer skin. The efficiency of my method left something to be desired and, realising that a set of clothing was going to take me all summer at that rate, I began to research skin processing. At the time this was just one aspect of a broad range of traditional living skills I was attempting to learn. Later, after a five-year period where I put parts of this knowledge to everyday use, whilst living in a remote area of Colorado without running water or electricity, I returned to university to complete an undergraduate degree in Anthropology.

The time spent studying in the four-field system of Physical, Linguistic, Cultural Anthropology and Archaeology favoured in the USA, made it clear that my interests lay mainly in archaeology, and especially in the field of experimental archaeology. My academic pursuits led me to an internship at the National Museum of Natural History in Washington, DC (hereafter abbreviated to NMNH). This three-month internship working on a multi-partner project (Rogers *et al.*, 2012) and subsequent short project contracts from the museum cemented my interest in pursuing an academic career in Archaeology. However, it also highlighted that, for me, library research was not enough, and without the opportunity to incorporate my set of practical skills I would not be satisfied with my work.

This realisation set me looking for postgraduate programmes specialising in experimental archaeology. A well-timed and much-appreciated referral from one of the curators at the Smithsonian led me to the University of Exeter, which at the time was the only University offering an MA in experimental archaeology. After finishing the internship and subsequent contracts with the NMNH, I crossed the Atlantic in pursuit of a way to combine my academic and practical skill set. The experience gained over the course of the yearlong MA finally allowed the construction of a PhD proposal – one that would advance an archaeological understanding of tanning technologies. Here is the result: it is presented in the hopes of filling the gap in information about very early skin processing technologies, and in the general understanding of the tanning process that had been thwarting my research since its earliest days.

All photographs contained in this work, unless otherwise stated, are the sole copywrite of the author.

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Introduction

This project came about because of the lack of systematic information available concerning skin processing technologies used in prehistory. Early tanning practices comprised of simple technologies (simple in that many of the individual steps used in modern tanning are condensed into a more contained set of processes) are not well understood, not only by researchers but by the general public. This is often evident in depictions of tanning in both traditional museums and their open-air counterparts. The information which was available often showed a less than ideal level of understanding concerning the processes necessary to transform a raw skin from a recent kill into a stable product and usable commodity. To rectify this lack of information about prehistoric skin processing, a project designed to record the tannage technologies of a large selection of prehistoric skin artefacts could provide a broad overview of what technologies were in use where and when. This would give a broad picture of the various tanning technologies geographical movements and changes through time. However, further research revealed that a systematic method for determining the tannage method used to produce archaeological skin items did not exist. Therefore, what was originally meant to be a study focused on analysing an extensive number of archaeologically recovered skin items became the project at hand; developing a systematic method for differentiating between prehistoric tannage technologies.

In practice, the initial goals of the PhD have become a postdoctoral project. It was recognised that the key step in fulfilling those future goals was to establish a methodology for filling the gap in identifying the earliest and simplest of tannage technologies. This gap in the research on skin processing led to drawing up the chronological parameters which excluded many of the more well-known later period sites (such as the Roman age site of Vindolanda) many of which contain large amounts of archaeologically recovered skin items (van Driel-Murray, 2001). A secondary goal was to analyse a few archaeological items from many different preservation contexts, providing a sufficient number of case studies to show that the method can be applied. To draw any conclusions about broader archaeological issues, a much larger range of archaeological sample analysis will be necessary.

Aims and Methodology

- Aim 1: Establish a simple, broadly applicable technique for identifying very early period tanning technologies based on the design, production and analysis of a broadly relevant reference collection.
- Aim 2: Test the method across a range of preservation contexts.

It was apparent that different surface textures and handling qualities can be seen as well as felt. In the fabric industry, 'handle' is used to describe the feel of a fabric including its softness, sponginess, flexibility and various surface appearances (Pan *et al.*, 1988). This term has previously been used to describe similar qualities in processed skins (Haines, 1991a). It was thought that these visual and textural differences would be still more distinct under magnification. The method was chosen based on personal experience with tanning technologies and a basic understanding of tanning chemistry. It was felt that a microscopic aspect was worth pursuing in addition to macroscopic observations and that, by characterising observable tanning effects in a modern sample collection, it would allow for assessment of the characteristics of ancient samples in a more formal way. This approach was conceived working from the hypothesis that different tanning technologies, using vastly different tanning agents, and yielding very different end products, would create an individual pattern of distinguishing characteristics potentially indicative of each tannage technology or of a category of grouped tannage sub-types. Discussions showed that the method for identifying these differences would need to be rigorous. The observation of characteristics would be inherently qualitative, so an extensive comparative collection would be needed, alongside a systematic and standardised system of evaluating the identifying characteristics. The comparative collection would need to cover not only a large number of tannage technologies, but also a range of species, in order to be relevant to the large geographic and chronological scope of the project.

Once established, these identifying characteristics could then be compared to archaeological pieces and, if found, would provide information concerning the tanning technologies employed during the artefact's life. In addition, because this type of analysis relies in part on the identification traits, which are established prior to the deposition of an artefact, subsequent processing such as secondary tannage is less problematic than with methods which rely on the present chemical composition or state of the artefact. A method based on differences in visual and physical characteristics would also fulfil the need for portability and simplicity, as the museum collections of archaeological leather are difficult to transport to a lab for analysis and each museum differs in what kind of facilities it can offer a researcher. Personal experience showed that many small museums would be the repositories for interesting material but that these museums might be able to offer limited or no microscope facilities.

Previous Methods

While not a completely novel concept, previous microscopic work on processed skin (Dempsey, 1984; Hains, 1957; Reed, 1972; Tancous, 1986) has focused more on modern tanning methods, or issues of importance to the commercial tanning industry, and the methods outlined have not yet been applied extensively in an archaeological context or used to analyse methods of skin processing used prehistorically. Reed (1972) deals with archaeological leathers but focused more on historical periods rather than early prehistory. He gives a useful overview of chemical tests used to identify the presence of tannin and aluminium, which are expanded upon in chapter 1 of this research. He also includes a chapter on the physical examination of skin from the standpoint of identifying the species involved and differentiating between skin artefacts and plant-based papers in terms of artefacts such as papyrus. The methods covered include standard light microscopy of surfaces, vertical and horizontal sections, electron microscopy and analysis of skin samples dissolved into solution. In addition to Reed's work, Betty Haines' book on processed skin and leather microscopy (Haines, 1957) provides a sound introduction to sectioning and skin morphology as a whole, as well as containing a well laid-out photographic reference collection for commonly used species identification. Relatively little has since been done with the intent of identifying different prehistoric tanning technologies microscopically though Reed and Haines' methods for observing processed skin have provided the building blocks to develop a methodology specific to archaeological leather. The method developed in the ensuing chapters is simple, portable, non-invasive, needs little specialised equipment and lends itself to analysing bulk samples at a reasonable cost.

Defining the Parameters of the Research

Though the project's purpose was to develop and test a method of identifying characteristics unique to different tannage technologies – technologies which were most likely in use globally – putting together a sample collection of species which were globally relevant was unrealistic. Instead, a set of geographic parameters encompassing North America and Europe were used to narrow the species targeted for the sample collection to a large but manageable number.

Geographical Boundary

The loosely delineated region of Europe encompasses, for this project, the islands of both Great Britain and Ireland, and Scandinavia as the northern and western borders, the northern coastline of the Mediterranean as the southern border, and as far east as the Ural mountains. North America is defined for this project as the land mass bordered to the east and west by the Atlantic and Pacific Oceans respectively, to the north as far as human occupation has been documented, and as far south as the end of the dry climate zones of Northern Mexico. This southern border is based on both the poor preservation potential for skin based products, and the lack of ethnographic evidence for their use in the warm, humid climates further to the south.

Chronological Boundary

The time frame bracketing these areas is based in part on the existence of well-dated hide artefacts; some of the earliest come from frozen sites, such as Zhokhov in Siberia, and date to approximately 8500 BP (Bruce Bradley pers. comm.). Within Europe, the oldest preserved skin artefact at present is a shoe found in Armenia which has been dated to 3627-3377 Cal BC (5646-5396 BP) in the Armenian Chalcolithic (Pinhasi *et al.*, 2010). Though the oldest hide finds fall outside this project's geographic scope, they do prove that hide items can and have survived from these very early periods. As such, the time frame for the project has been pushed back to include the Mesolithic (with some species being pertinent to the Palaeolithic, as there is indirect evidence for clothing from images and tools from the Upper-Palaeolithic (Cook, 2013: 22-23, 61-62, (Hayden, 2002) in the hope that the sample collection will stay relevant to any future items found which date significantly earlier.

The paucity of finds from early periods may not be due solely to their length of interment. Rather, it may be a reflection of the types of tannages being used, as it is widely held that vegetable tans, at least in wet contexts, preserve better than other traditional tannage types (van Driel-Murray, 2001: 185). It could also reflect the quality of the tannage, with light vegetable tans, containing relatively small amounts of fixed tannin, preserving less consistently than later examples. These later examples were subjected to more systematic and often longer processes, allowing higher concentrations of tannin to affix to the dermal fibres and thereby increasing their preservation potential. Due to the Romans' heavy use of the vegetable tanning process and their well-documented methods for producing it (Reed, 1972: 90-91; Thompson, 1982: 143; van Driel-Murray, 2002b: 261), the upper end of the time frame for this research ends with the Roman Expansion and the assumption that large scale vegetable tanning followed in their wake (van Driel-Murray, 2000: 299; 2001: 185; 2002b: 252). As this occurrence varies across the region, so too does the upper time limit placed on this research.

The Focus of the Research

The tannage method focus, chronological and geographical scope all serve to narrow the breadth of archaeological collections considered for analysis during the testing phase of the research. Previous research in Europe has focused on later time periods such as Roman and Medieval from which large collections of skin items exist. The focus of this research is on some of the earliest applications of tannage technologies. Those that fell outside the geographic or temporal boundaries, as a number of important collections did, had to be assigned to a (hopefully) future research project. That being said, during the testing phase, when archaeologically recovered items from eight museums on two continents were being examined to determine if and how well the identifying tannage characteristics survived in various preservation contexts, some artefacts dated to later periods were examined in an effort to answer specific questions. Some skin items dated to the Roman period were observed, as they were good examples of what was almost certainly classic vegetable tan. These were found in the same preservation environments as the earlier artefacts and therefore made excellent comparative material, as very few of the earlier artefacts showed characteristics associated with a classic standardised vegetable tanning process. In the case of bog or wet site preservation the later Roman items served as a gauge when attempting to observe the level of secondary tannage from contact with environmental tannins present in skin items from earlier periods, which were less likely to have been vegetable tanned originally.

Inclusion of Ethnographic Items

A number of ethnographic items from North America were also included, as many had direct relevance to the archaeological material being analysed. The same is of course not true of Europe, as many of the time scales differ significantly. Though the ethnology of North America is not directly relevant to Europe, many of the climate zones and preservation environments were and are. The use of ethnology and culture studies as a way of fleshing out some of the more ephemeral parts of past living skills, especially on a technology basis, has relevance to both North American and very early European skin processing traditions as, from an environmental viewpoint, many of the tannage technologies are pertinent to both locations and many others around the world. In addition, the amounts of stiffening due to age and the effects of conservation treatments displayed by the ethnographic items had applicability to the entirety of the project's geographic scope.

The primary aim of the archaeological analysis was to assess the method's effectiveness when presented with the challenges of archaeologically recovered items from a variety of preservation contexts. They were intended to discern what traits identifiable to tannage type survived, if any, and to what level those that did survive could be used to inform the observer of the original tannage type used. While this research has the potential to allow for large-scale mapping of tannage technologies in use prehistorically, the archaeological analysis undertaken to develop this methodology was never intended to fulfill this goal. Instead, chapter 9 presents a stand alone case study which seeks to highlight how the methodology can be applied to archaeological and ethnographic skin items, to provide information about not only tannage type, but faunal use, construction sequences, and in some cases the item's use-life.

Emerging Techniques: Future Research

The main goal of this research was to develop a simple method based on visual and physical characteristics for investigating prehistoric hide tanning, and test that method on archaeologically recovered material. However, a number of lines of complementary investigation have presented themselves and are outlined in chapter 1. Gas Chromatography and Mass Spectrometry are at the top of this list as potential secondary analysis methods for addressing specific issues, or after a primary analysis method such as microscopy have assessed the potential value of other analysis. The more invasive nature of these analysis types, which often require sampling of what are often rare and fragile items, mean that they can never been applied as routine. However, despite this drawback, when used as complementary secondary analysis techniques alongside non-invasive primary methods, these element analysis methods could potentially allow for the identification of specific lipids and plant materials. This could take the research away from simple classification of vegetable, fat/smoke, or mineral tans and rawhide and into the realm of identifying individual ingredients used in the tanning process. This ability to identify specific tanning technologies, as well as pinpoint individual components of those technologies, would provide unprecedented information on regional differences or similarities. This includes technology shifts precipitated by the influx of people or ideas into or out of these regions. The mapping of an everyday technology such as hide tanning in a temporal and spatial context would provide a fascinating look at prehistoric people's interaction with both the floral and faunal elements of their environment and with each other.

Once realized, the application of this method would give archaeologists the ability to identify and subsequently catalogue the various skin processing technologies that existed during prehistory. This data set could reveal a great deal of information about people's migration patterns, the invention or adoption of new technologies, and trade routes of tanning agents or secondary ingredients not indigenous to their area of discovery. This would open up avenues of inquiry previously denied to research due to an absence of a solid and broad data set on the subject.

Chapter 1

Connecting Disciplines and Traditions in Archaeological Skin Processing Research

1.1 Introduction to Current Analysis Techniques for Processed Skin

The processing of animal skins into wearable or utilitarian material is an overlooked and underappreciated technology, which was of the utmost importance in the day-to-day lives of ancient peoples. Whilst much has been written on skins, fur and leathers, most of the available literature has focused on topics other than how the skin was processed, or on the more recent tanning technologies which adhere to the parameters for the modern definition of leather (Cameron, 1991; Popa and Kern, 2009; Reed, 1972; Schaffer, 1974; International Council of Tanners, 1968; van Driel-Murray, 2000; Bazzanella, 2005; Calnan, 1991; Calnan and Haines, 1991; Chahine, 1991; Goubitz, 1984; Hollemeyer *et al.*, 2008; Strzelczyk *et al.*, 1997). This work, in contrast, emphasises the simpler hide processing technologies. Thus, this research defines skin processing as 'the preservation and manipulation of animal skins to prevent decay and produce a material which is suited to its required task'. Having the capability to process skins is as important in the spread and development of humans as stone tool production and the control of fire. In order to move out of warm environments, the ability to manufacture a mobile shelter, that maintains body heat, and allows an individual to range far enough afield, for a long enough period of time to procure food and other supplies essential to maintaining their existence, is of paramount importance. Skin processing allowed people to cut the umbilical cord which would otherwise tie them to permanent shelters and fire.

While this technology played a central role in the livelihood of prehistoric peoples, early evidence of tanning can be difficult to discern. In many areas, variations of fat and smoke tanning technologies were used – a method that leaves little physical evidence behind other than the rare instance where we find the processed skin itself. Though the preservation of processed skin in an archaeological context is rare, it is found often enough to provide a reasonable array of examples from which to theorise about how, when and where various tanning technologies arose and were disseminated around the world. These existing examples of processed skin items provide a unique opportunity to investigate this set of complex and diverse technologies. At present, the analysis of these finds is often descriptive, giving good information on dimensions, appearance, stitching and patterning, as well as thoughts on what the item may have been when in use. In many cases, analysis is hampered by the fragmentary state of the finds, and, while important, archaeological skin products often have an appearance which can discourage interest and research in the subject in favour of more visually appealing artefacts.

1.2 Identification of Species

One avenue of inquiry which has been pursued for many processed skin finds is the identification of the species from which an artefact was made. This has been attempted through long standing techniques such as the analysis of hair shaft features, grain pattern, and, more recently, DNA (Reed, 1972; Harrison, 2002; Leon Augustus, 1920;

Ryder, 1980; Appleyard, 1978; Campana *et al.*, 2010; Poulakakis *et al.*, 2007; Schlumbaum *et al.*, 2010; Vuissoz *et al.*, 2007). The most definitive of these is DNA testing, but this method is seldom achievable on a large scale due to cost, lack of necessary lab facilities, or inability to gain sampling permission (Poulakakis *et al.*, 2007; Vuissoz *et al.*, 2007; Schlumbaum *et al.*, 2010). Furthermore, not all hide artefacts have suitable DNA surviving, and the state of preservation as well as past conservation treatments may adversely affect the viability of this kind of analysis.

Speciation using morphological traits most often relies on hair shaft analysis and matching the grain pattern against modern reference collections. The grain pattern is created by the hair follicles, from which the hair has been removed during the de-hairing process. The distribution and density of these tiny holes varies between species, creating unique patterns that, when well preserved, can be used to identify the species of origin (Haines, 1991a; Reed, 1972). Some short comings which affect this process are the preservation state of the grain surface, poorly cleaned artefacts and items which have had conservation treatments heavily applied. Another consideration is the change undergone in the coats of domesticates during the intervening years since the artefact was lost or disposed of. A good example of this is the difficulty in differentiating between early goat and sheep skins, as early sheep breeds had sparser and hairier coats, more akin to goats than many modern sheep varieties (Ryder, 1981; 1983). This consideration influenced which domestic breeds were chosen for inclusion in the sample collection produced for this research. Based on this, an attempt was made to use breeds which are thought to most closely resemble their earlier predecessors.

Hair shaft analysis is a microscopic method where, if present, hair can be used in conjunction with sample collections to identify or, at least, narrow down the species of origin used in archaeological skin artefacts (Appleyard, 1978; Leon Augustus, 1920; Harrison, 2002; Ryder, 1980). This can of course be complicated by poorly preserved hair, or hair for which no comparison sample is available. In the case of archaeological finds, it is also possible that the ancient hair is too different from its modern descendants to be positively identified.

Recently the use of protein analysis from preserved hairs has also been attempted, using hair from a legging belonging to Ötzi, the well-preserved Chalcolithic mummy from the Hauslabjoch (Hollemeyer *et al.*, 2008; Egg *et al.*, 2009; Spindler, 1994). This method uses the peptide ion patterns derived from tryptic hair digests, then compares these patterns to patterns produced by known species. This returned a result which best matched sheep, in contrast to the morphological analysis which indicated goat as the most likely species from which the legging was made (Hollemeyer *et al.*, 2008). This peptide analysis was also undertaken in an effort to identify the species of origin for the pelt found during the White Horse Hill excavation in the UK (Hurcombe pers. comm.). This has since been returned as European Brown Bear after a DNA test was performed. While this technique has proven to be quite accurate, it is worth remembering that there are species such as the Aurochs, now extinct, for which no comparative sample exists. This dilemma may extend into early breeds of domesticates as well.

Lastly, and perhaps with the most accuracy, DNA analysis has opened a fascinating window into prehistoric skin artefacts. While the potential to use DNA on archaeological leather has been recognized (Poulakakis *et al.*, 2007; Vuissoz *et al.*, 2007), it is not often exploited due to cost, lack of necessary lab equipment, or artefacts which are either unsuitable for sampling, or from which sampling is not allowed (Schlumbaum *et al*, 2009). Molecular levels of analysis have penetrated archaeological thought since the nineties and early twenty first century. This has influenced conservation methods which have begun to concern themselves with not only preserving hide artefacts for display but conserving these using methods which do not compromise later DNA, protein and lipid analysis. One notable use of DNA analysis on archaeological leather comes from Bern, Switzerland. There, after an attempt at identifying the species of origin for the Neolithic legging found at Schnidejoch Pass in the Swiss Alps, using morphologic means, failed to provide conclusive results, it was sampled and sent for DNA testing. The mitochondrial cytochrome 6 was used to identify the maternal haplotype of the species used for the processed skin of the legging. It was identified definitively as domestic goat (*Capra aegagrus hircus*) and surprisingly showed a haplotype not thought to have been present in Europe until 2000 years later, and which is today found only in Laos (Schlumbaum *et al*, 2009). This successful use of DNA analysis to identify species highlights its usefulness as a tool in archaeological processed skin research and, as the technology becomes more readily available and the cost diminishes, there is hope that it will become a more feasible and frequently used analytical method.

1.3 Identification of Tannage Technologies: Current Methods

This focus on the speciation of processed skin artefacts is important, as it adds empirical information to our understanding of animal utilization. However, there is more to the overall story of animal selection and utilization than just the animal of origin. The ability to identify and eventually map the technologies used to process these skins adds another dimension to this understanding, as the species being tanned can influence the tannage method chosen, and the tannage methods available can influence prey selection. Not all species have skins suited to all tannage types. For example, wild boar (*Sus scrofa*) is extremely difficult to fat tan and results in a stiff product with little drape. If a person were going hunting with the intent of replacing a pair of leggings which were wearing thin, boar is unlikely to be the sought-after animal if a variation of fat tanning were the only method in use at the time. However, it would be a desirable choice for rawhide products such as shoe soles or armour, which require tough, thick skin. This bias could well play into the slaughter age of domestic animals as well. Adult cattle skin and calf skin are very different in nature. Calf skin is much more feasible for clothing production, especially using fat and smoke tanning technologies, whereas the thickness of adult cattle skin can be difficult to fat tan, but can be vegetable tanned with better success, producing a thick, dense and durable product for straps, shoe soles, and tack. When looked at on a larger scale, these influences could offer interesting insight into early human hunting and herding strategies.

As useful as this information could potentially be, at present investigating tanning technologies can be difficult due to the ephemeral nature of the processes, and the difficulty in acquiring samples from what is an infrequently preserved material. However, some attempts using various methods have been made. While many methods have centred on identifying tannins that may or may not be present in the samples, others have offered up a variety of ways which attempt to identify other less well documented technologies.

Tannins are secondary metabolites of vegetable origin around which there remains much discussion. They are thought to play a role in protecting a plant from insect, herbivore, fungi, and bacterial attack and are broken down into two groups, condensed and hydrolysable tannins (Bickley, 1991). Reed (1972: 265-79) offers a number of ways to detect the presence of tannins by dissolving small samples into solution, to which reagents are added, forming precipitates if tannin is indeed present. He highlights a similar test for detecting the presence of aluminium when alum taw is suspected. For tannins, this can be taken further toward identifying specific types of tannins by introducing iron salts, which show blue in the presence of pyrogallol (hydrolysable) tannins, and green when catechol (condensed) type tannins are present (Reed, 1972: 271). This reaction was well known in ancient times, and often exploited by dyers and ink makers to produce a black pigment which was permanent (fast) (Reed, 1972; van Driel-Murray, 2002a).

This ability of iron salts to change colour when combined with tannin has also been capitalised on by Carol van Driel-Murray (2002a) to suggest a field test for the presence of tannins. The article published in the *Journal of Archaeological Science* outlined a technique designed to test for the presence of tannin, thereby indicating that an item may have been vegetable tanned. This technique is based on the colour change produced when tannin comes into contact with iron. A tiny amount of solution containing 2% ferrous sulphate ($FeSO_4$) in distilled water is brushed onto an unobtrusive area. If tannins are present a black colouration will develop. This method has the obvious drawback of leaving a permanent mark on the artefact, but this can be mitigated by separating a few fibres from the main piece to which to apply the solution, then viewing these with a hand lens or microscope to look for the change in colour. Also, in its favour is the simplicity of the technique, as it requires little specialised equipment and the solution is easy to produce, maintain and transport, making it suitable for large scale application.

As with any technique, however, there are some limitations; it is only applicable to one type of tannage technology (vegetable tan), and a positive reaction is achieved if any tannin is present, including tannin introduced after the skin was processed. These could come from stains applied for decoration, intentional secondary tannage intended to change the colour or characteristics of the skin, and unintentional post depositional secondary tannage from the surrounding environment, such as that seen in peat bogs. This limits the technique's use to dry or frozen site preservation scenarios. This technique was trialled on 170 different samples excavated from Qasr Ibrim in Egypt and and proved quite effective at identifying the presence of tannins (van Driel-Murray, 2002a).

Problems also arise for all of the iron interaction methods, if the skin items have been preserved in iron-bearing layers of soil. The presence of iron causes insoluble complexes to form within the processed skins, which are difficult to extract into solution. In these conditions, Fe salts are inconclusive as, due to the tannins' contact with environmental iron, the colour change used as an indicator has already occurred (Reed, 1972: 267; van Driel-Murray, 2002a: 19).

Another test suggested by Reed (1972: 252-264) involves cutting a very thin slice off the side of an object to reveal a fresh edge. When this is examined under UV light, fluorescence indicates the absence of tannins. Both tannins alone and the collagen material in raw and processed skins will fluoresce strongly under UV light, though interestingly, if the tannins are combined with collagen, as happens in a vegetable tan, neither fluoresces. This fluorescence can also be used diagnostically to assess the depth to which tannin bearing surface treatments penetrated the skin's thickness, again being especially useful on freshly cut cross sections.

A 1999 article in *Antiquity* (Groenman-van Waateringe, 1999) took a novel approach to accessing the original production techniques used to process skin prehistorically. The pollen content of some of the hair-on clothing used by the Iceman was analysed, and when two distinct categories of pollen for the same plant species were found, an attempt was made to determine if this difference could be due to how the skin was processed. One set of pollen grains was plump and dark, while others from the same plant species were pale and shrunken. It was hypothesized that this difference could be accounted for by pollen present in the hair when the skin went through the preparation process, and pollen which was deposited later during the life of the clothing and was therefore not exposed to any tanning agents. Both fresh pollen alone and fresh pollen rubbed onto skin samples were subjected to a number of processes known to be associated with skin preparation. The results showed that the combination of hot smoke and the presence of grease caused both a reduction in size and the loss of colour of the pollen grains that was seen in the archaeological samples. This supports the idea that the Iceman's hair-on clothing at least may have been fat tanned then smoked.

A few drawbacks to this approach are its limited applicability to a large percentage of European skin finds, of which most are preserved in a wet environment which would likely severely reduce the pollen load or wash it away altogether. The research would also have benefited from some skins which were coated with the pollen, then put through the entire series of tanning processes, perhaps with pollen samples being collected at the completion of each stage, so as to better replicate the possible scenarios which could have taken place to produce the material for the Iceman's clothing. Some basic misunderstandings of hide production are also apparent within the article, as are a few oft-repeated inaccuracies about the permanence of smoke tanning. A fat tan is indeed a reversible process, however, once the skin is smoked well, it is no longer reversible due to the introductions and cross linkages of aldehydes and phenols, as well as small amounts of tar. If washed with detergent, the oils can be stripped from the skin, but not the smoke, resulting in a stiff skin similar to the condition seen in vegetable tan that has not been oiled (fat liquored). However, the skin never reverts to the hard, crusty condition with cemented fibre structure seen in rawhide products.

It was mentioned that heat reflected from the smoking pit sides was useful and that fresh cow dung was used to create smoke (Groenman-van Wateringe *et al.*, 1999: 887). While smoke is essential to the process, heat is not. Very well controlled warmth can cause the oxidation of certain types of fats, mostly unsaturated such as those found in brains, liver and marine animal oils. However, unless very well-controlled, heat will cause irreparable damage to the collagen in the dermis, and the temperature at which this damage is caused is lowered significantly if the skin is damp. This means that using anything wet enough to produce steam on the fire is potentially problematic in terms of a wearable end product. Secondly, the heavy body fats used in this experiment are unlikely to benefit from heat, other than to facilitate penetration by making the fats more liquid. This type of fat generally oxidises at a temperature higher than the shrinkage temperature of the skins' collagen, which is around 65°C for collagen which has not interacted with tannins or metal salts (Sykes, 1991).

Other than the minor problems in some aspects of the tanning procedure, this unconventional attempt at accessing prehistoric tanning technologies is a step in the right direction. It provides a very useful way of gaining additional support when fat and aldehyde tannage is suspected, a tannage type which is notoriously difficult to identify in the archaeological record.

Though far out of the geographical area covered by this research, a study done in South Africa to assess the efficacy of ochre as a tanning agent should also be mentioned here (Rifkin, 2011). This research compared various tanning ingredients, including numerous types of locally sourced minerals, by applying the ingredients to skin samples then assessing the samples at predetermined time intervals, based on eight measurable categories. This rigid assessment method included subjective and non-subjective criteria. The subjective criteria were measured using ordinal scales of one to five for hide pliability, fungal and saprophagic activity and odour. These standardised assessment methods make this research important, in that other experimentally produced sample collections can be directly compared to its results. Using this study as a reflection of the level of pliability given by the different tannage types is problematic however, in that most traditional tannages are not static technologies. That is to say that applying the ingredients at intervals, then leaving the skin samples to their own devices for lengthy periods of time, is not an accurate reflection of the procedure of skin processing, especially concerning fat tans. However, the conclusions drawn by this study as to the interactions between some types of ochre and dermal material should be noted. It was found that varieties of ochre are able to inhibit collagenase and act as antibacterial and antifungal agents, and their application to skin can prevent the onset of decay (Rifkin, 2011: 149).

Two methods using more sophisticated technology, which have been applied on a small scale to differentiate between tanning types, are gas chromatography and mass spectrometry (Spangenberg *et al.*, 2010; Luo *et al.*, 2011). GC-MS was carried out on samples for skin artefacts found on Schnidejoch pass. These artefacts lend themselves well to sensitive analysis methods, as they have been cleaned and conserved without the use of chemical additives, which subsequently made them good candidates for microscopic analysis as well (Spangenberg *et al.*, 2010). Using a method which is better known for its use in pottery analysis the team compared the isotopic composition of the main fatty acids to that of a modern reference collection.

This analysis identified the presence of exogenous animal lipids, and an abundance of lipids of vegetable origin, and based on this information, concluded that some form of plant based aqueous solution was being employed during the skin processing procedure. This evidence supports a very early use of vegetable materials in the tanning process (Spangenberg *et al.*, 2010).

Again, this study would have benefited from a wider sample collection of known traditional tannages, to compare with the results from the archaeological leather samples, as the only traditional tannage included for comparison was a piece of brain-tanned mule deer (*Odocoileus hemionus*) skin. However, this leaves this type of large-scale comparative work open for future research; research that will comprise one aspect of an anticipated post-doctoral project using the author's modern sample collection as a starting point.

A second article published in CHIMIA (Püntener and Moss, 2010) used infra-red spectroscopy to search for fatty components of the processed skins worn by the Iceman, after the presence of tannins and metal salts was ruled out. This technique measures an infra-red beam which passes into the sample from a crystal. The spectrum collected shows bands which match known substances. These matches are used to detail the chemical composition of the sample. The study found a high concentration of calcium salts and saturated fatty acids in the Iceman's skin clothing. These findings did not match any of the control samples of archaeological, historical, modern and ethnographic samples used for comparison. However, when the team saponified the body fat of non-marine based mammals using wood ashes, a similar chemical signature was achieved. This led them to theorise that the tanning method employed for producing the Iceman's clothing used adipose tissue that had been mixed with wood ashes, which was incorporated into the dermal tissue in large part as calcium stearate (Püntener and Moss, 2010: 319). While more ethnographic tans were used as comparisons for this study, including a tanned fish skin from Siberia, there is still a lack of any kind of sizable comparison body of data on which to base tannage assumptions. Many types of fat tans ethnographically used wood ash as a de-hairing agent and, depending on the level of rinsing a skin was given after this procedure, this could account for the saponified fats seen in the study. Fats are added just after the de-hairing stage and prior to the softening stage in this type of tannage. It would be interesting to see if a skin prepared in this way gave matching results. If not, it would support the idea that wood ashes were being used in a much wider variety of ways within the various skin processing procedures than previously assumed. Soap is frequent ingredient in many historical tanning processes and provides another possibility which could account for the chemical signature seen in this study.

1.4 Identification of Tannage Technologies: Advancing Current Capabilities

These sophisticated means for identifying tannage technologies have provided exciting initial results. These results would be even more informative if contextualized with in a larger comparative data set. Such information could be provided by sampling a modern reference collection composed of known traditional tanning technologies and variations thereof. While the results of these new techniques are promising, they can be expensive, require specialized lab conditions and are (with the exception of IR) invasive, in that they require samples to be cut from the artefacts. Aside from more extensive testing of these advanced analyses, what is needed to further this field of research, and what this PhD research seeks to provide, is the use of commonly available technology, alongside extensive and systematic reference collections, as a method for differentiating between past tanning technologies (van Driel-Murray, 2002a; Groenman-van Waateringe, 1999). This would provide a simple, accessible and inexpensive way to add to the collective knowledge of skin processing technologies.

1.5 Terminology Concerns and Clarification

In addition to working toward a more standardised means of identifying tannage technologies, this discourse attempts to clarify some terminology concerns. The various tanning processes, and the multitude of ways in which they are accomplished, have a large variety of vocabulary applied to them, much of which comes from modern day industrial tanning. While some of this terminology is perfectly acceptable, other parts are unsuitable or just erroneous when applied to prehistoric or traditional tannage types. There are also differences in the way vocabulary is used by traditional tanners, who often employ the craft practices relevant to their part of the world, and the modern commercial tanning industry, as well as by archaeologists recovering and studying processed skin items. This is confusing not only to tanners and potential tanners, but also to researchers attempting to apply this vocabulary when discussing archaeological skin working. Interesting and important insights into tanning technologies exist within the commercial industry, archaeology and the different communities of craft practice. However, what could be very fruitful interdisciplinary interaction and overlap is often hampered by a lack of clear terminology, in relation to pre-modern tanning technologies and processes.

There is also an aspect of elitism from all sides of this discourse, with commercial industry viewing traditional tans as inferior 'pseudo' leathers when compared with today's products. Many traditional tanners view the highly scientific and chemistry-heavy field of modern tanning as inapplicable to forms of tanning practiced ethnographically, and within the community of craft practice today. These ethnographic or traditional tanning processes consolidate many of the steps which modern tanning science separates out into individual procedures, making them a more condensed form of tanning. Specialist leather researchers of many disciplines have a tendency to quote less often from knowledge accumulated and disseminated by the community of craft practice, from which most traditional tanners originate. Perhaps they are concerned that this body of knowledge lacks the academic credentials preferred when referencing for publication. Instead, they may choose to use terminology and concepts gleaned from the more scientific and better referenced modern tanning industries which, as mentioned previously, may not be the most appropriate or applicable comparison, when speaking about pre-modern or especially, prehistoric tannage technologies.

While personal prejudices within various groups are difficult to remedy, agreeing upon and clarifying a set of terminology which fosters knowledge transfer between parties with disparate backgrounds is an achievable and worthwhile first step. The following section will attempt to begin this process by discussing a few terms which have frequently been assigned different meanings by the various groups, as well as introduce some new terminology in an effort to create a more transparent dialogue between these different interest groups. This terminology discussion will also streamline the following academic discourse on the subject.

The terms *leather*, and consequently *tanned* are, for the general public, overarching terms applied to any skin product which is soft, opaque and flexible. However, from a scientific point of view the term *leather* should only be applied to a skin product meeting the criteria of being chemically stable/non-reversible, imputrescible when wet, retaining its original fibre structure in a dry state and having a wet shrinkage temperature higher than that of raw skin (Reed, 1966; Reed, 1972; Sykes, 1991). *Tanning*, in the strictest sense, should only be applied to skins which were processed using vegetable tannins. This is why, historically, using Alum to process skins was referred to as *tawing*, not tanning (Sykes, 1991; Reed, 1972; FAO, 1960). And while, as pointed out by Sykes (1991), these criteria cannot be expected to be applied in a hard and fast manner in light of the various kinds of leathers in existence, the disparity between the theoretical and common usage for *tanning* and *leather* is problematic. In newer texts, these more stringent definitions have relaxed somewhat, as less emphasis is placed on the more measurable qualities such as shrinkage temperature in defining what can be called leather, and what can be termed tanned. Perhaps the most current consolidated resource on tanning (Covington, 2011) reflects today's more generalised use of these terms and defines *leather* as 'Hide or skin with its original fibrous structure more or less intact, *tanned* to be imputrescible' and defines *tanned* as the 'conversion of putrescible organic material into a stable material capable of resisting biochemical attack' (Covington, 2011: xxxviii-xxx).

This restriction on the use of the terms 'tanned' and 'leather' led to perhaps the most prevalent example of a term failing to communicate its intended meaning. This surrounds the use of the words *rawhide* and *untanned* skin, in regard to prehistoric processed skin artefacts. These terms have been used to denote items made from skin, which is not obviously vegetable tanned, in keeping with the post Roman industrial tradition, in an effort to remain true to the rigid definition of *leather* and *tanning*. This is a definition which would relegate most ethnographic tannages as to this *untanned* classification, including the majority of North American and Arctic fat tanned items. Referring to these items thusly gives a skewed impression of the complexities of the skin processing technologies being employed, and the properties inherent in the material resulting from them. This goes on to misinform later assumptions about clothing manufacture and general skin working, which are made based around the characteristics possessed by each type of tanning technology.

While it is true that many of these skin items are not vegetable tanned, they are certainly not untanned or raw skin (skin as it exists immediately after being removed from an animal) or rawhide (an untanned skin treated to be hard, stiff, and often translucent). This usage gives rise to a picture of prehistoric humans walking around wearing de-fleshed but otherwise unprocessed skins, that would quickly lose the hair and then rot off their bodies; or, if made from rawhide, what would essentially be clothing with the fit and feel of a cardboard box. If one were willing to deal with these downsides, there remains the dilemma of attempting to hunt whilst smelling like carrion and hunting successfully enough to replace your less-than-ideal attire every few weeks.

The use of terms such as 'semi-tanned' or 'pseudo tans' are much more accurate, but unfortunately give the impression that these traditional tanning technologies are somehow less advanced or less useful than those tans which fall within the modern qualifications for *leather* (vegetable, chromium, and aluminium tans) in the scientific sense of the word. Thus, a new term is required. I have opted to use the phrase *processed skin* as a general term when talking about prehistoric skin products, as it gives an accurate description of the time, effort and care which goes into traditional tanning technologies without ascribing any specific attributes to the finished skin products. *Tanning*, however, I have chosen to retain in its common usage, as the word is ubiquitous to any discussion on skin products, and universally understood to mean ‘changing a raw skin product into something more useful and pleasant to have on one’s body and inside one’s home’. Therefore, in the interest of readability and clarity the six different tanning technologies are referred to herein as tans, even though some unsmoked fat tans, alum taw and especially urine tan do not qualify as tanned under the more stringent criteria laid out earlier.

Technologies used to produce hard skin products with a minimum of processing, such as parchment and parfleche, do not fit even the common usage of the word tanned. In keeping with this, these products will be referred to as Rawhide when a generalized term is needed. When speaking about any of the tannages individually, they will be referred to by their technology or subtype thereof; *i.e.* Rawhide with a subtype being parchment, Fat tan with numerous different subtypes based on the variety of fat or oil used and their oxidative characteristics; vegetable tan with subtypes which fall into a wide spectrum, roughly based on the amount of fixed tannins and how the tannins are introduced into the dermis; and mineral tans, a subtype being alum taw. All other terminology used in this research will be elaborated on over the course of the text, as well as being included in a glossary of terms to make the discussion as transparent as possible.

Another notable misunderstanding, or at least oversimplification, which bears discussing here, is the concept of chewing skins as a major softening technique applied during traditional tanning processes. Though the original instance which prompted this oft repeated notion has not been clearly identified, one can speculate that it was a misinterpretation by some intrepid observer of native practices over the years. As it stands, this was not and is not an efficient or practical means of softening an entire skin and is not conducive to producing an end product with a pleasant handle. From a cognitive standpoint, it seems unlikely that people capable of making complex stone tools, skilled abstract art, and weapons which increased mechanical advantage, would settle for such an inefficient method for undertaking what is likely to have been a daily chore.

Perhaps more convincing yet are the practical implications inherent to the chewing concept. The large number of skins a person would need to tan per year to adequately clothe themselves in a seasonal climate, even without taking into account clothing a family or producing the skins necessary for bedding and other domestic needs, should put this idea to rest. In the North East region of North America, Gramly (1977: 602) estimates that each person would need at least 3.5 deer skins per year for clothing alone (Figuring a set of clothing lasts two years and each person had only one set) which means the Ontario Huron population, estimated at 18,000 at the time of European contact, would need to tan 64,000 deer skins per year to keep up with the general clothing requirements. While other authors debate the conclusions he draws concerning population conflict based on hides as a contested resource, none challenge his estimates other than to state they may be a bit low, an observation with which this author agrees (Gramly, 1977; Turner and Santley, 1979; Webster, 1979). Much further to the north, the Nunamiut of Nunavik who wore caribou skin clothing (often in double layers) all year long estimate that fifty to sixty skins a year, were needed for a family of five, including two and a half skins per person for bedding. In areas with a slightly warmer climate thirty skins are the estimate per family per year (Issenman, 2000: 71). The rate of attrition on an individual’s teeth would soon render them unable to eat properly if they were to attempt to soften enough skins to maintain this level of production.

There is legitimate mention of this as a supplementary technique for dealing with a stiff spot, rewetting a small part of a skin and for crimping the edges of mukluk soles (a style of arctic boot) (Oakes and Riewe, 1995), though using the teeth to crimp the mukluk seam edges, as opposed to an ivory or bone implement designed for this task, appears to be local specific. The local nature of chewing as a softening or clothing manufacturing technique may be supported archaeologically by research showing mandibles with differing musculoskeletal stress markers (MSM) between two groups of Alaskan Natives. These conclusions were drawn based on an osteological collection which spanned a period of time from 300 years ago to 80 years ago, and showed that, at the time, people from Golovin Bay were likely using their anterior teeth in a way that people from Nunivak Island were not (Steen, 2005). The osteological findings are supported by a statement from Margret Lantis, a woman from Nunavik Island, saying that women in her area rarely chewed hides during processing or subsequent clothing manufacture (Steen, 2005: 129). There is also ethnographic documentation of removing the fat from bird skins by using the teeth and sucking the fat off the surface (Oakes and Riewe, 1995: 47), a practice possibly mistaken for softening.

While there are many ways in which skin can be softened and later manipulated for domestic purposes, the concept of chewing hides soft as a ubiquitous part of early skin processing technologies should be seriously questioned. This is not to say that chewing skins soft has never been done, nor that it cannot be done, simply that it should not be repeated as a foregone conclusion.

1.6 Conclusion

As demonstrated here, the attempt to identify tannage technologies used in prehistory is not new. However, a systematic and standardised method of analysing and discussing these technologies would benefit this field of research. This research aims to provide a methodology of this nature. A sample collection covering key species of importance for North American and Europe, each tanned using six widely used tannage technologies, has been produced and analysed for discriminating traits which indicate tannage types. The use of these traits has subsequently been tested against a select number of archaeological objects from a variety of preservation environments, as well as some ethnographic material. The time scale available for completing this PhD research can in no way cover the breadth of the fieldwork and comparison collections needed to complete this type of methodology. Though an effort has been made to begin the process, the majority of detailed analyses of archaeological pieces will be written up as a selection of Journal articles in conjunction with the museums housing the objects.

Chapter 2

Investigating Early Tanning Technologies

2.1 Introduction to Methodology and Skin Morphology

Chapter 1 sought to provide the following: an overview of current analysis methods and studies which have previously been applied to skin objects; some issues within the discourse surrounding processed skin research; and an introduction to the proposed methodology laid out in the ensuing chapters. In this chapter, physical differences between the tannage types, and the implications these have regarding the chaîne opératoire, are discussed. These are framed as possible choices made by a tanner in regard to achieving a predetermined end product. This discussion is needed to understand the complexity inherent in analysing a product, which is the result of a process that can begin with selecting a prey species and culminate in the production of a skin object that may be subjected to multiple factors – not only over its use-life, but also during its interment and post depositional treatment.

2.2 Developed Method of Systematic Analysis of Skin Artefacts

The founding principle of the methodology developed for this research is that different tanning technologies produce processed skin products with varying individual characteristics. These characteristics would have been familiar to early tanners and would influence what types of items would be made from each tannage type. Some of the more practical differences between the tanning technologies and the implications for skin working, are based on the author's extensive experience and generalised knowledge exchange with in the traditional tanning community of practice. A brief overview of some of the variation between tannage types follows.

Vegetable tan tears more easily than fat tan of the same thickness but can be made much more water resistant and has less stretch. It can also withstand much higher temperatures than fat tan before melting the collagen fibres, allowing it to be heat treated to form thicker harder pieces that hold their shape indefinitely, making it useful for vessels and invaluable in early armour (Reed, 1972; Sykes, 1991).

Fat tan, which can have the grain layer removed or left intact, offers superior breathability, is soft with a large amount of stretch, and has a high tensile strength for uses such as sewing lace. It withstands the slightly acidic nature of sweat better than vegetable tan making it a useful under layer of clothing prior to the use of textiles (Chahine, 1991; Kamper, 2016).

Rawhide dries hard and can be stretched when wet, allowing for significant shrinkage as it dries, making it a high-quality binding material. It is more water resistant than fat tan, urine tan, vegetable tan or alum taw, due to the intact nature of its ground substance (ground substance is composed of soluble interfibrillary proteins and mucous). The ground substance dries hard, encasing the dermal fibres in a hydrophobic covering which can be improved upon by coating the nearly dry product with a heavy oil or wax. If dried under only moderate tension and oiled, rawhide will be translucent. This property was exploited during the Medieval to make window material, magnifying glasses and even spectacles before glass was commonly available (Richards, 1997; Kamper, 2016; Reed, 1972).

Alum taw, when not exposed to dampness, has a reputation for long term durability. This is evidenced by the many early book bindings produced using alum tawed skin which still exist in good condition. It has a high tensile strength and is still the specified tannage for cricket balls. If wetted, however, the alum and salt are washed from the skin and as the skin dries it returns to a stiff and unusable state (Haines, 1991a; Thomson, 2009).

Urine tan reduces the tendency for the grain to crack, allowing a grain-on fat tanned skin to be more easily produced, this can be made more effectively water resistant than grain-off fat tans.grain-off fat tans. This grain on material is lighter in weight than vegetable tan, making it a good choice for packs or outer garments where weight is a concern (Kamper, 2015).

Smoke tan can be used alone but is often used in combination with a variety of fat tans and imparts greater softness retention upon repeated wet and dry cycles (Richards, 1997; Riggs, 1980). This effect is due to the addition of aldehydes and phenols present in the smoke (Haines, 1991c).

This short review of some key differences between tanning types clearly shows the complex choices to be made between desired features and tanning technologies, but this is still not the full range of options available. Many of these tannage types can and have been used in sequence, to produce combination tans. These allow a tanner to further modify their product using these combinations in an effort to mitigate properties which would be undesirable in the finished product, or to add properties that the original tan lacked. An example would be a fat tannage over-tanned (re-tanned) using vegetable tannins. This combination reduces the fat tan's tendency to over stretch and lose shape, by adding tannins which tighten the overall fibre structure. The addition of tannins increases the skin's weight slightly and gives the skin a denser, stiffer handle by further filling the interfibrillary spaces and adding cross linkages between the dermal fibres. Using vegetable materials to colour fat tanned skins may have be the precursor to their use as a tanning material, as skin workers would have noted the resulting change in the behavioural characteristics of the dyed skins.

Smoke being used either prior to or after tanning with fat, urine, or even rawhide is, in essence, a combination tan. This combination is very ancient, and fat tan and smoking are so interconnected that they are often talked about as a single technology. They are, however, two separate technologies with differing properties and chemical components. The smoke adds aldehydes and phenols to the processed skin as well as oxidizing some of the lipids present producing a more durable and hydrophobic product which retains its softness and handle more readily upon drying out (Richards, 1997; Riggs, 1980; Haines, 1991c; Covington, 2011). In some areas smoke has also been used to increase the ability of alum to withstand moisture (Haines, 1991b). It also discourages insect infestation and damage and smoked skin is less appealing to dogs (Kamper, 2016). An example of a more modern combination tan is Dongola leather (often referred to as Latigo). This is a method where alum taw has been over-tanned with a vegetable tan often using Gambier (pan tropical plants of the genus uncaria which contain high levels of Catechin tannins (http://en.wikipedia.org/wiki/Uncaria). This produces tough, durable leather, suitable for use outdoors as it possesses a superior resistance to wetting (Thomson, 2009).

The individual characteristics of each tanning method, once introduced or discovered, would influence a host of other cultural aspects such as clothing style and construction techniques, notably shoe styles, as well as tent construction, armour, and animal harness and tack. The adoption of new technologies, allowing for more efficient mass-production, could have preceded trade specialisation, as well as producing an identifiable trade surplus, pointing toward areas that may have other archaeological evidence of large-scale production.

2.3 Overview of Chosen Tanning Technologies

Tanning animal skins is thought of, and often presented as, a complex process requiring expert knowledge. While the chemistry behind tanning and the make-up of skin itself can be quite sophisticated, one does not need to be a chemist to successfully tan skins. An understanding of the physical properties of organic materials acquired by prehistoric peoples though daily activities such as, food preservation (drying, salting, rendering and smoking) gave them the base knowledge to preserve and manipulate dermal material. Curiosity and trial and error, combined with the cognitive ability to recognise cause and effect are, in the author's opinion, the requirements needed to lay the groundwork for the development of tanning technologies. Skin processing is a reasonably straightforward combination of mechanical manipulation and chemical processes, which produces a diverse array of different skin products. Choices are made throughout the process by the tanner to achieve the desired final product. Choices based on what it will be used for and what properties it must possess to fulfil that role. Though there are countless different options, these options can be grouped and the choices broken down into three main categories. These choices are not an argument for inevitability or deterministic pathways within tanning technologies but are rather the practical parameters of what is possible. The three categories are as follows.

A. Reductive treatments
B. Additive treatments

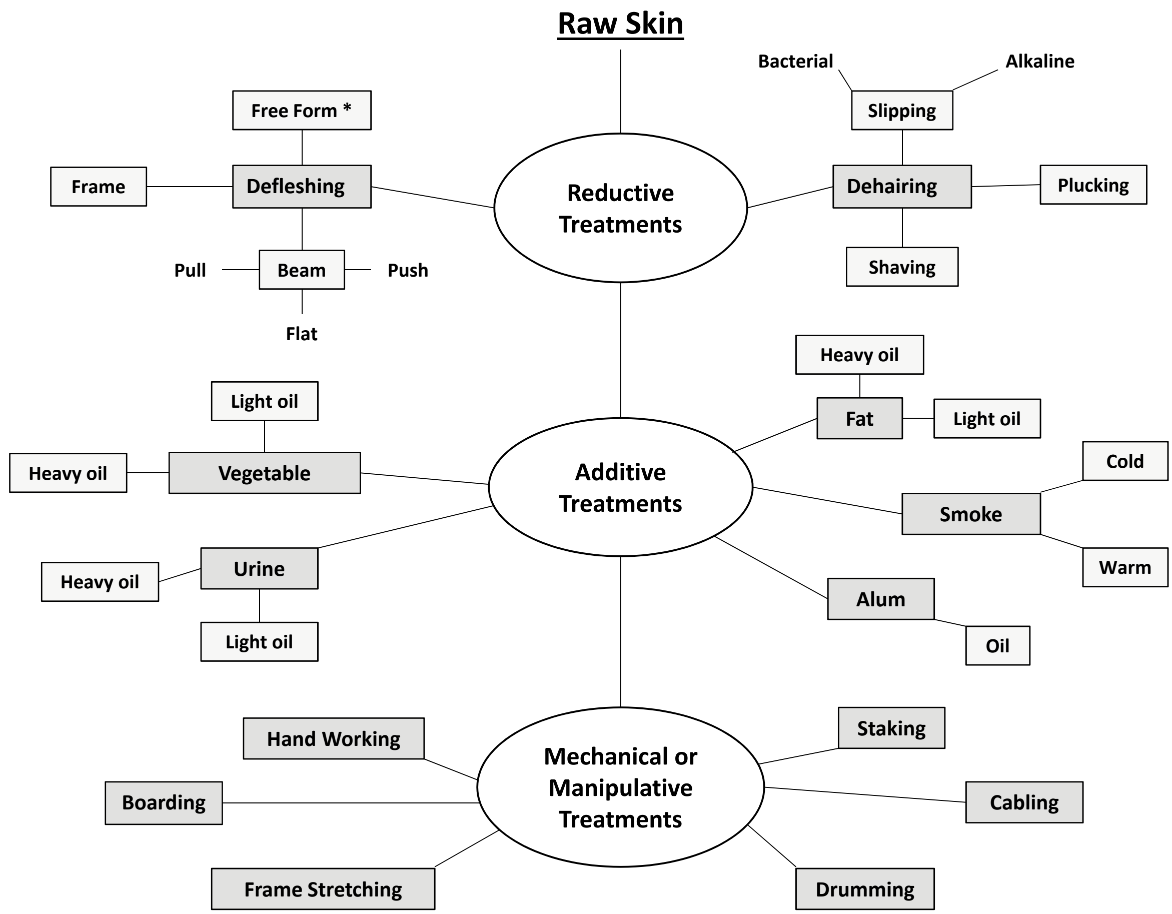


Figure. 2.3-1. Some of the variation possible from the raw skin to the finished product.*non-formalised method of flesh removal such as scraping flesh off over the leg or on the ground.

C. Mechanical/Manipulative treatments

A. Reductive treatments remove something such as the hair, the grain layer, ground substance and in some cases dermal thickness. These are usually done prior to tanning and are often referred to as pre-processes or pre-tanning processes.

B. Additive treatments introduce things such as tannins, minerals, or oils to the skin. This is also the stage where most chemical processes happen, and is the stage most often referred to as 'tanning'.

C. Mechanical or Manipulative treatments are generally concerned with moving the fibres of the dermis against each other in such a way that they do not set up or harden as the skin dries. There are numerous names which describe this process, and, in the case of tans done with the grain layer intact, how this is done affects the appearance of the grain surface.

Various authors have attempted to format generalised technological sequences for tanning processes, but none have focused on the more condensed traditional tanning technologies. Figure. 2.3-1 is this author's attempt to give clarity to the steps in common, whilst also showing the extensive variation possible.

There are a vast number of different tanning techniques, many of which are simply the personal preference of the individual tanner. The various tanning technologies, however, fall within more discrete boundaries. To clarify, a skin can be de-fleshed wet or dry; and can be hung in a frame or draped over a beam, but this still produces the same rawhide end product if nothing else is done to it. A bit further into the treatment process, tannins can be introduced by rubbing, steeping, or full immersion. However, no matter how they are applied, they do the same job within the dermal fibres,

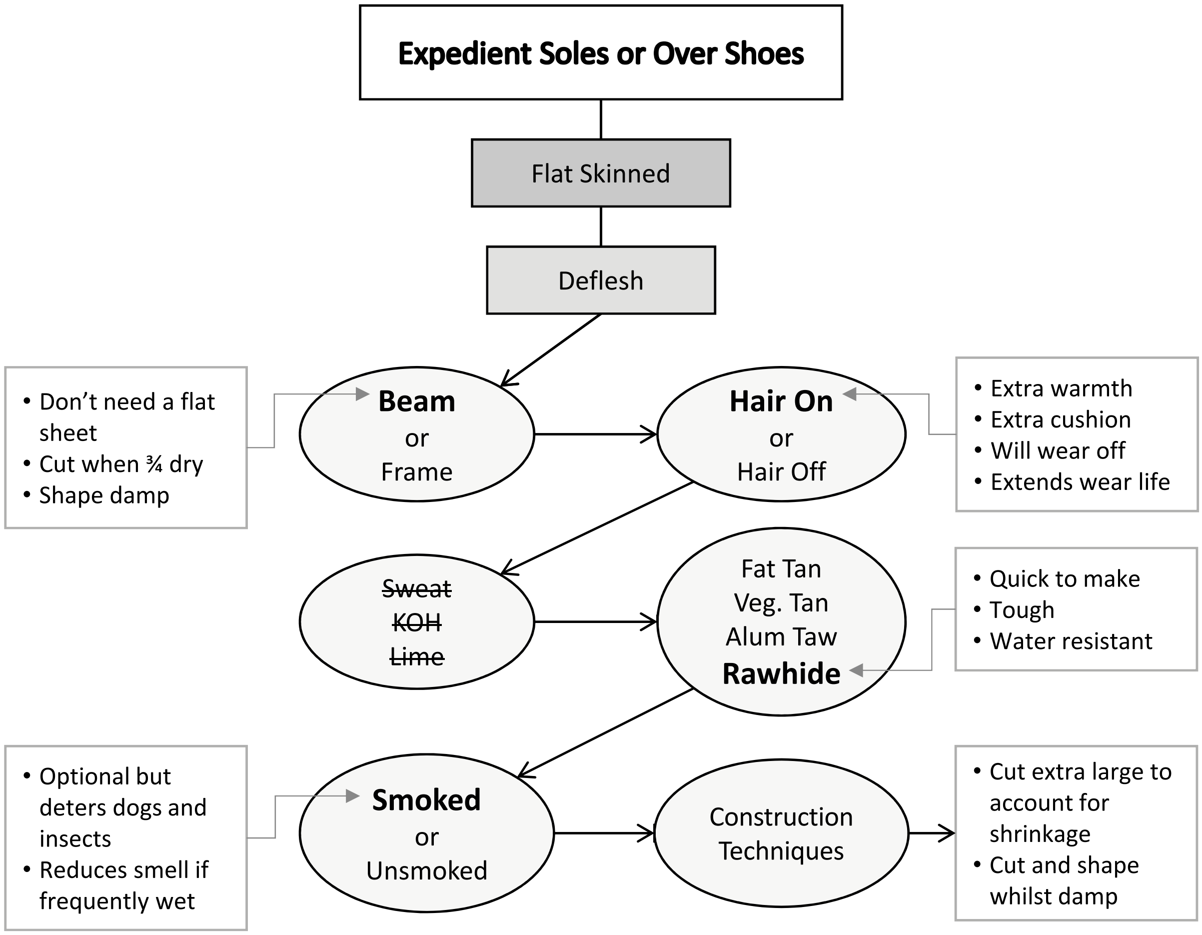


Figure. 2.3-2. An example of a possibly choice progression when the desired end product is a product made from rawhide.

and produce a vegetable tanned product with a set of observable properties inherent to vegetable tannage. The same theory applies to fat and mineral tans. In summary, how the tanning agent is introduced or applied causes only minor variations to the finished product when compared with the difference between finished products using different tanning agents.

These tanning agents lend their names to the various skin processing technologies, which can be sorted into roughly, five groups. What follows is a brief overview of these five technology groups. A more in-depth discussion of each tannage type, including a brief description of the chemistry at work during each, can be found in chapter 4. These technologies each possess a set of observable characteristics individual to that technology type:

1. Mineral tans
2. Vegetable tans
3. Fat and Oil tans
4. Smoke tans
5. Rawhide derivatives

1. Mineral tannages use mineral salts to form stable bonds with the collagen in the dermis. Alum is the only mineral to be used prior to the second half of the 18th century. The aluminium portion of Alum is the active tanning agent, and, when combined with common salt, produces a white, soft, stretchy product with a high tensile strength and long term durability, as long as it is kept dry (Haines, 1991a; Sykes, 1991; Thomson, 2009).

2. Vegetable tans are produced by introducing tannins into the dermal fibre network. Tannins are present in all plants, and are thought to protect plants from insects, fungi and bacterial attack. Certain plants such as sumac, acacia, oak, willow, alder and chestnut have higher concentrations of tannins than other plants and have all been used historically for tanning. The tannins also vary in concentration between plant parts, and bark, seed pods, fruit, roots and galls have all found use in the tanning industry. Vegetable tan produces a water resistant, grain-on product with a dense fibre

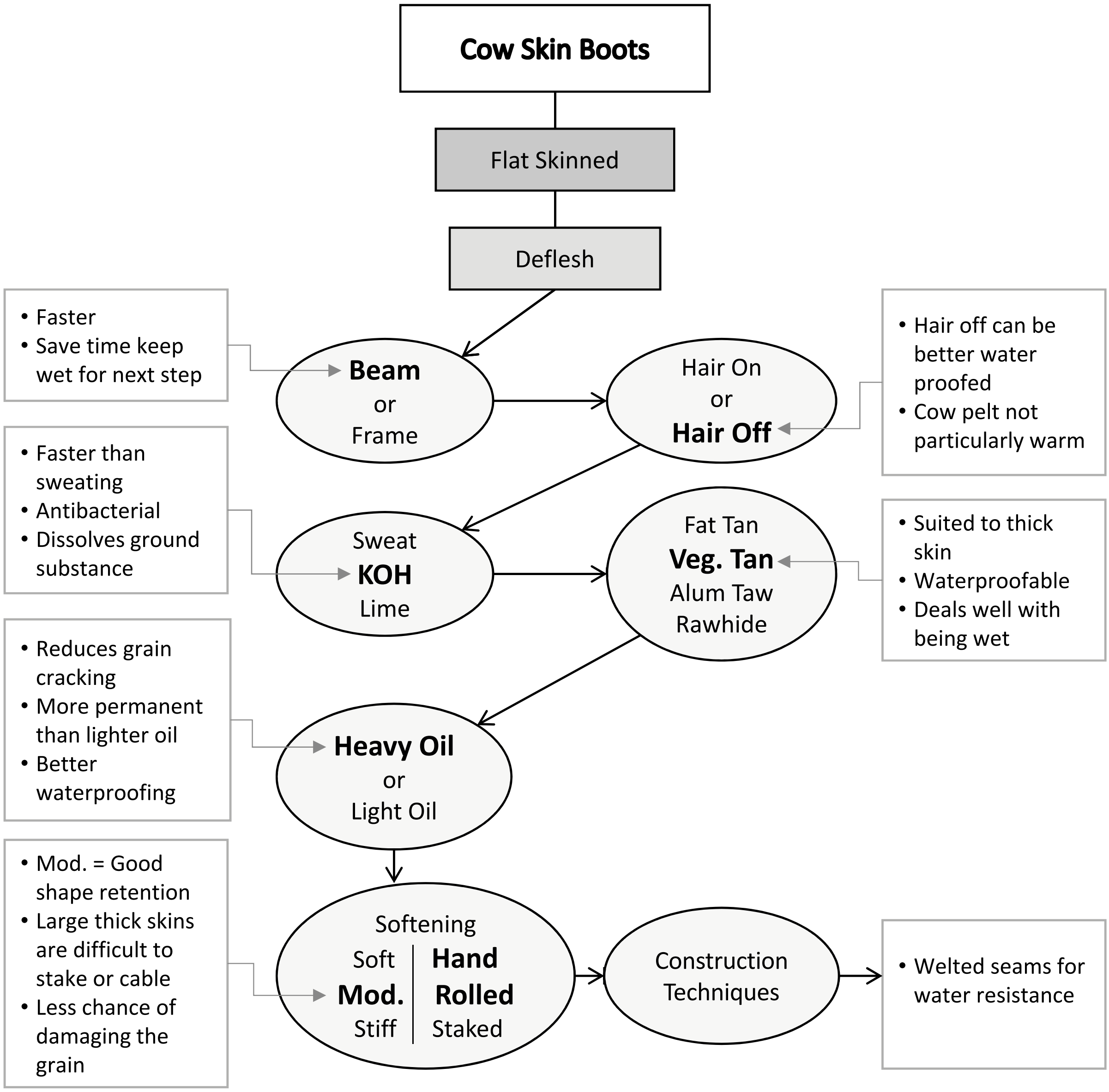


Figure. 2.3-3. An example of a possible choice progression when the desired end product is a pair of boots, and domestic cow is the available species.

structure and a moderately stiff handle (Bickley, 1991; Rahme, 1996; Richards, 1997; Thomson, 1991a).

3. Oil or fat tans are produced by adding emulsified oils to prepared skin, and, when combined with manual manipulation, result in a soft, stretchy and light weight product. This technology includes two sub-groups (both of which often have the grain layer removed, as its fibre structure is very dense and can impede good oil penetration), intentionally oxidised oil tannage such as modern day chamois using cod oil; and fat tans using brains, egg, liver and other sources of oil which are oxidised to a lesser extent than seen in modern chamois tanning. Both types of fat tan produce soft, stretchy, suede skins with a full (soft and spongy) handle (Reed, 1972; Haines, 1991a; Richards, 1997). Though not observed as often in modern ethnographic practices, the use of vegetable oils in skin processing should be kept in mind. Sesame oil was used to treat skins in ancient Egypt and Mesopotamia, and it has been suggested that gold-of-pleasure (*Camelina sativa*) could have been employed for this purpose in prehistoric Europe (van Driel-Murray, 2002: 254, van Driel-

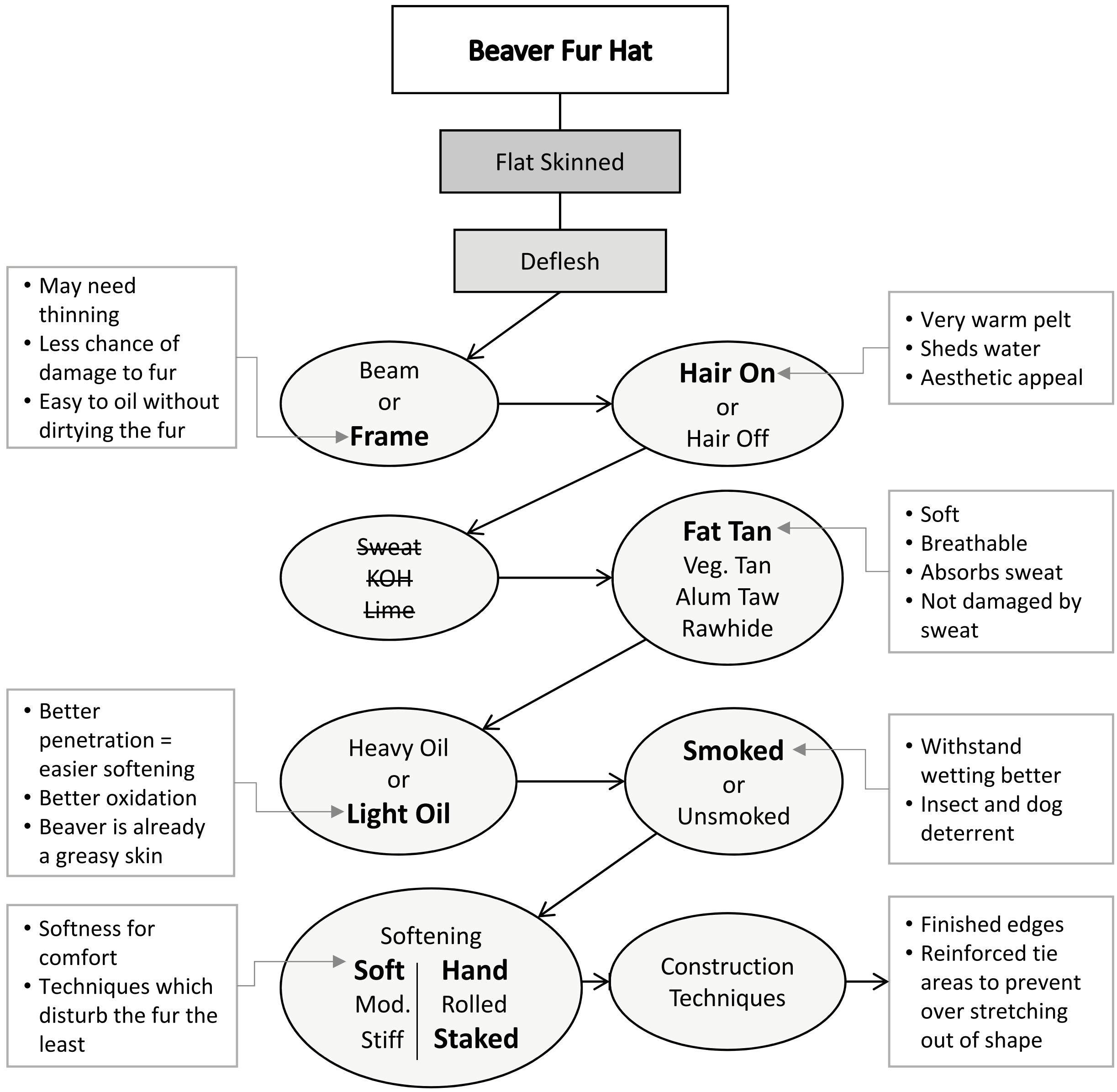


Figure. 2.3-4. An example of a possible choice progression when the desired end product is a fur hat, and beaver (*Castor sp.*) is the available species.

Murray, 2000: 303). Experiment might clarify the role of vegetable oils, but this method has not been explored further in this study.

4. Smoke tannage is often used in conjunction with other tannages such as fat tan, alum taw and rawhide, but is also used as a standalone technology in parts of China (Covington, 1997). The smoke introduces aldehydes and phenols to the skin which makes the products fibres more hydrophobic, allowing the skin to be wetted and/or washed without losing as much of the soft handle as an unsmoked skin would. There is a tendency to talk about white fat tans being useless without being smoked, especially when discussing North American tanning traditions. This is simply not the case. Unsmoked fat tans do not turn back into rawhide. They simply require a more rigorous re-softening process than if they were also smoked. However, these subsequent softenings are not as long or arduous as initial softening during the tanning process. the There are many groups which did not smoke their fat tanned skins in areas such as the desert South West and some arctic communities, where the chances of skins being frequently wetted are slim (Klokkernes, 2007; Richards, 1997). These kinds of correlations are worth keeping in mind when studying leather from other dry areas, such as Egypt.

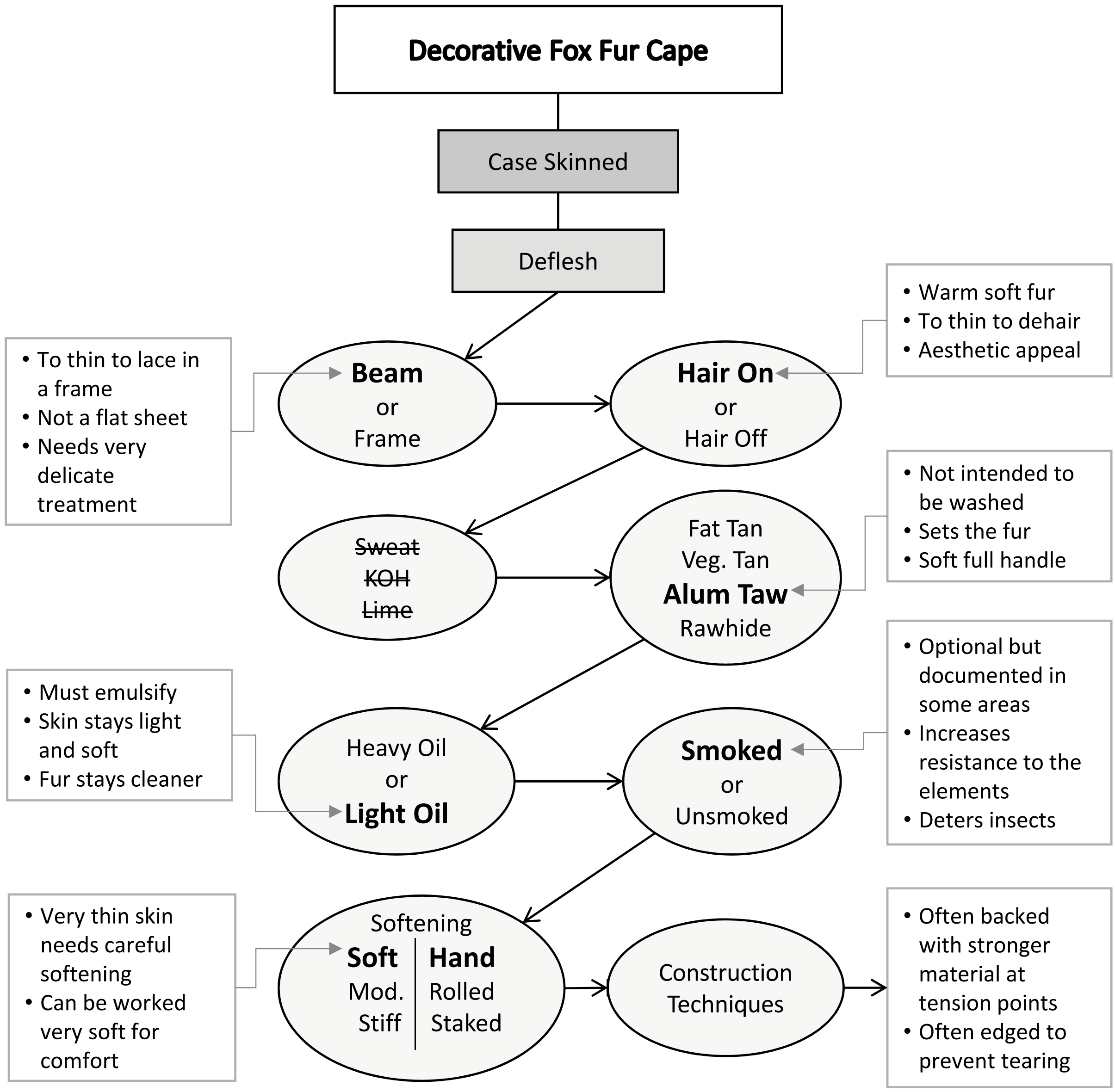


Figure. 2.3-5. An example of a possible choice progression when the desired end product is a fur cape, and fox (*Vulpes sp.*) is the available species.

5. Rawhide is simply de-fleshed skin without any other actions employed to remove the interfibrillary ground substance, which causes raw-hide to dry hard and stiff. It can be de-haired or made with the hair or fur left in place, as is seen with some pairs of expedient prehistoric footwear. Various finishing techniques have been used for producing specialty rawhide products such as parchment, window material and Parfleche (Reed, 1972; Richards, 1997; Rahme, 1996).

This profusion of choice may look daunting in its scale, but when put into a utilitarian context, the decisions are more straightforward. The following Figures 2.3-2 through 2.3-5 seek to illustrate the possible choices a tanner makes when tanning a skin for a predetermined end product. Again, these are simply options which can be chosen, and not a rigid progression.

The six skin processing technologies or techniques chosen for this research are as follows: vegetable tan, alum taw, rawhide and three variations of fat or fat and smoke tan (wet and dry scrape brain tan and urine tan). They were used to build a comparative sample collection, and were chosen based on ethnographic, archaeological and historical evidence of their use over a broad time span and wide geographical region. Alternatively, as in the case of alum taw, there was direct evidence that the ingredients necessary for producing the tannage type were available and known to specific cultures present at the time. Alum has documented use as a mordant in the dyeing industry as early as 1000 BC in the Middle East and Northern Africa and, as skin is often dyed, it is not a great leap to allow for the possibility of its use as a tanning agent in these and surrounding areas as well (Reed, 1972; Thomson, 2009; van Driel-Murray, 2000).

2.4 Layers of Object Biography

It is recognised that processed skin artefacts are not produced then immediately discarded, and that each has a complex story, of which the identification of the skin's tannage type is only a small part. With this in mind, several layers of chaîne opératoire were considered when observing both the modern sample collection of clothing made from traditionally tanned skins, and the objects accessed in museum collections.

Sewing and Cordage

It is understood there are other layers of information that stitching types, sewing materials and construction techniques provide, but these are not the focus of this research. That being said, some of these construction choices can be, at least in part, chosen due to the constraints or strengths of the initial tanning technology of the skin being worked with. There are extensive ethnographic texts and archaeological analyses written on these subjects, and while this research may in the future add more information to research on sewing and construction techniques, for now the author would refer readers to these more expert discourses on the subject (Issenman, 2011; Gleba and Mannering, 2012; Harris, 2009; Wilder, 1976; Oakes and Riewe, 1995; Goubitz, 1984; Volken, 2014).

Wear and Tear

Repair and the item's use during life leave distinct traces which can be diagnostic. These in-life use traces include stitching holes, cut edges, modifications such as patches, and the general stretch pattern of an area under tension. These elements behave differently between the different tannage types and, when present, can provide information not only indicative of tannage type, but of the production sequence and even, in some cases, signs which point to how, and in what state, the item was used. Chapter 7 has been devoted to this important analysis strategy.

Archaeological, Experimental Interment and Preservation Issues

While issues raised by interment environments and state of preservation are by no means laid to rest by this work, an attempt has been made to address these issues by choosing to analyse artefacts from a wide range of different preservation contexts. These contexts include wet, dry, frozen and anaerobically preserved artefacts spanning two continents. In addition to investigating archaeological artefacts from differing preservation contexts, some samples were made and then buried at the beginning of this research in 2011, to be excavated and analysed microscopically after three years. As these burial experiments were done with known tannage types, it was hoped that they would provide interesting information concerning degradation patterns. Unfortunately, none of the samples were able to be recovered after the three-year time period had passed, due to unforeseeable circumstances. It is hoped that this experiment can be repeated as part of the planned post doc research.

Post Excavation Treatments

Conservation and storage concerns are also worth noting for this research. Most archaeological skin items have been treated in some way in the hopes of warding off insects, preventing rot, slowing the drying process, or a host of various techniques geared toward stabilizing the structure in some manner. Treatments used in the past have the potential to affect the traits used for identification of tannage type, as well as any future chemical analysis undertaken. This potential has been addressed, and the current thoughts on the conservation of processed skin artefacts detailed in chapter 8.

2.5 Conclusion

This chapter sought to introduce some of the complexity inherent in this research both pre and post deposition and the chaîne opératoire involved tanning technologies. The brief discussion of the overall practice of tanning, and the progression of choices open to a tanner, highlights the breadth of skin processing as a field of research. It is made clear, however, that while practical skill and experience are necessary to produce useable products, an in-depth understanding of chemistry is not. With this in mind, the common tannages which would have been available to prehistoric peoples, and which were chosen for this research, have been laid out and briefly described. Following on from the choice of tanning technologies used for this research, chapter 3 reviews prehistoric faunal utilization, as a means of informing the species selection for the comparative sample collection of processed skins. As many tanning technologies cover wide geographic swathes, an extensive collection of species from both North America and Europe was needed to produce the most comparable collection possible within the restraints of the research timeline.

Chapter 3

Rationale for Faunal Selection

3.1 Introduction to Faunal Selection Chapter

The importance of the arguments to be made when selecting species, and the rationale behind some specific species being chosen over others, was a crucial methodological underpinning for the construction of a modern sample collection, and as such a dedicated chapter has been devoted to faunal selection. No reference collection could hope to cover all the possible species across the northern hemisphere. The parameters were instead to cover a range of fur bearers vs haired species; provide some larger and smaller species; cover key wild and domesticated species and select species relevant to the archaeological record of two continents. Though a large portion of the discussion that follows references archaeological sources, personal contacts and experiences from the ancestral skills communities were the axis for much of the final work. The faunal selection for this project is thus based on a vast field of knowledge on animal behaviour, ecosystems on two continents, complex arguments on chronological environmental shifts and various pathways to domesticated varieties, all of which are highly individual.

Key Species of Economic Importance

Over the course of human history, animal exploitation exhibits a large amount of variability. This variability has been influenced by environmental changes, cultural preference, landscape remodelling, evolving domestication technology, and, in those areas that developed domesticates, livestock availability and suitability to regional climates. Within this variability, however, there are key species which stand out as more economically important than others.

North America and Europe were chosen as two loosely defined sample regions. In an effort to build a comprehensive comparative collection of hide samples, species were chosen from these areas which were: important to each area as a whole; of significant regional importance within an area; or available and utilized throughout both areas.

This research defines economic importance as heavy utilization due to size, availability, ease of procurement or value (a loosely defined term applied to animals such as furbearers where caloric return is not the primary motivation). Depending on how difficult a species was to capture, or, in the case of domesticates, what amount of resources were required to raise each animal to a preferred slaughterable age, the resources gained from the animals needed to significantly outweigh the resources expended for them to count as economically important. While this is mainly a case of caloric return, value as a utilitarian resource as in the case of furs is also considered. As the focus of the research is on primary products rather than secondary such as milk or labour in the form of oxen plow horses etc, these aspects are only briefly considered.

Based on ethnographic accounts and archaeological evidence, large animals are highly prized, as they represent a significant amount of food and resources and require expending only the time and energy necessary to hunt or raise one animal. Animals such as rabbits, while not large, are often numerous, and can be driven and netted, or in captivity, bred rapidly in large numbers, making the return worth the effort involved in their capture or rearing. Others, such as small deer, while not large nor overly populous, were consistently available in many different environments and appear in the faunal record throughout the time period encompassed by this project.

Some species, such as many fur bearers, whose remains are found in numerous sites, represent a more complex commodity than simple calories (Charles, 1997; Barker, 1999; Halstead, 1992; Howard-Johnston, 1998; Issenman, 2011). Since they provide an insignificant amount of caloric return to offset the effort involved in hunting or trapping them, and in some case where the carcasses appear to have been discarded intact, it seems likely that the pelt was of primary interest (Rowley-Conway, 1995b). Some of the fur bearers represented at these sites may have been taken due to chance encounters while hunting for other, more desirable prey. However, based on the amount of remains and their large distribution, it seems probable that they were also sought after in their own right, perhaps as individual luxury items, as necessary clothing components in cold climates, or as valuable, lightweight trade items (Charles, 1997; Schmidt, 2009; Hurcombe, 2014).

Evaluation and Support of Selected Species

In order to evaluate and support the economic value of species considered for this project, a number of lines of research were incorporated using both direct and indirect evidence to support each species inclusion in the sample collection. This evidence was used to evaluate a species' temporal and spatial presence and use, relevant to the parameters of this project. Once selected based on this evidence, a third criterion was considered: the feasibility of sourcing a skin.

Direct evidence included significant presence in faunal assemblages, the presence of identified hair, fur and skin, and genetic analysis. In many areas, preserved leather finds (which have been attributed to species based on grain appearance, hair analysis, or genetic testing) strongly influenced species selection. These species were included in an effort to make the sample collection directly comparable to existing prehistoric processed skin objects. Lipid residue analysis of ceramic vessels definitively documenting the presence of dairying were also considered. Lipid residue analysis is capable of identifying the family of animals from which the lipids originated, such as ruminant, porcine or equine, and whether they are from milk or adipose tissue (Copley *et al.*, 2003; Outram *et al.*, 2009).

Indirect evidence included evidence of hunting, such as blinds and drive lines (which are believed to be associated with the capture of a specific species) and associated artefacts which support the presence of crafts using secondary animal products, notably spindle whorls for yarn production and ceramic sieves and whisks, similar to those used today for traditional cheese making (Barker, 1999). Art such as petroglyphs, pictographs, ceramic and bronze figurines show scenes in which specific species can often be recognised (Barker, 1999). Where available, ethnographic accounts were read to help contextualize the role and level of importance some species hold within traditional societies. These, however, mostly relate to North America and some small areas of far northern Europe.

From Hunting to Herding

Wild animals comprise the entire prehistoric faunal assemblage in North America, with the exception of dogs and in some areas, turkeys. Many of the animals exploited prehistorically still maintain much of their natural range and are mostly unchanged today. In Europe, wild game dominated the faunal assemblages as well until the early Neolithic, when domesticates began to appear in the archaeological record. Many of the European wild species are also extant and currently maintain healthy populations over large areas of their original ranges.

While debating the origins of domestication is not the focus of this research, it is an important consideration in the selection of species, and breeds within species, for creating a pertinent reference collection of skin samples. With many of the variables inherent in different herd use strategies such as, the age or sex of the animals being slaughtered, directly affecting the types of skins available for use. Domestication is a complex issue; what follows is a brief overview of topics relevant to the discussion on species selection

Domestication's roots, for western Eurasia, originated in the Near East approximately 10,000 years ago, apart from dogs whose domestication origins extend back as far as 40,000 BP (Budiansky, 1999; Fernández *et al.*, 2006; Germonpré *et al.*, 2009; Götherström *et al.*, 2005). In these areas groups began to protect, feed and care for some species, choosing to pursue a very different subsistence strategy. This newly adopted animal husbandry gave these groups a way of stockpiling animal resources against future shortages. This resource deferment behaviour led to long term changes in the economies across Eurasia (Alvard and Kuznar, 2001). With the episodic spread of domestication technology into Europe during the early Neolithic, animal use began to focus on a few species (Barker, 1999). In most areas of Europe, the domesticates; cattle, sheep, goats and pigs, dramatically replace wild game as the principal source of meat and primary animal resources.

A transition in animal husbandry toward the use of secondary products in addition to primary ones occurred in a regionalized way across Europe with some areas adopting the practices very early on and others later. Dairying appears to have occurred as early as the seventh millennium in parts of the Near East and south eastern

Europe (Evershed *et al.*, 2008; Salque *et al.*, 2013). These innovations in the use of secondary products would affect the age at which animals were slaughtered, as well as skin morphology (especially in animals raised primarily for wool). Calf, lamb, and kid skins would be more available in an economy focused on dairying; older juveniles with larger, thicker skins would be commonly butchered when meat was the focus; and a herd managed for wool is likely to have had a larger proportion of fully adult animals being slaughtered when they are past their prime wool producing years (4-7 years old) (Barker, 1999; Sherratt, 1983; Halstead, 1992; Higham, 1968; Payne, 1978).

Shifts in human animal exploitation not only changed which animals made up the bulk of the diet, but significantly changed their physical characteristics (Ryder, 1983: 16). Changes in size, general proportions, colouring, and coat type can all affect dermal thickness, fibre density, depth of hair shaft penetration, grain appearance, dermis to grain layer juncture and sub-cutaneous attachment characteristics (Reed, 1972). The changes in physical appearance and fur/hair type (Ryder, 1980) would likely affect skin usage as well. Both factors affect the skin's characteristics such as thickness and hair fastness (how well the hair stays attached after tanning) and the tightness of the grain at the mid-dermal junction and would dictate the type of tannage used and what the resulting leather would be suitable for. On a functional level changes such as coat type, would mean that an Iron Age cow with a short coarse coat would not make as nice a fur as would an aurochs with its softer, finer coat. On an aesthetic level, new colour variations could influence selection according to personal taste (Popa and Kern, 2009; Harris, 2009).

Collecting skins for the wild species chosen for inclusion in the collection is reasonably straightforward, as these animals as a species have changed little since the last ice age. The domestic species, however, were hunted initially as wild game and later raised as domesticates (Zeder, 2012). Many of the characteristics we think of as standard for domestic species, such as sheep with homogenous wool coats, small short-legged pigs with very little hair, and cattle with short conical horns and coarse short hair are all relatively recent traits, for which some have been selectively bred (Ryder, 1980). Finding a breed whose skin and fur closely resemble the oldest domesticated forms of each animal was very important. This continuity makes the sample collection more consistent with, and therefore more comparable to, the museum collections which were targeted for later comparative analysis.

3.2 Introduction to European Species Selection

As discussed in the introductory chapter the loosely defined region of Europe encompass the islands of both Great Britain and Ireland as the western border, and Scandinavia as the northern border. Greece and Italy as the southern border, and the Ural Mountains as the eastern border. The time frame bracketing these areas spans the Mesolithic (and possibly earlier) through to the Roman expansion. The time at which various areas of Europe came under Roman influence varies across the region, and due to this so too does the upper time limit placed on this research.

Key Species Use Through Time and General Trends

Sheep (*Ovis sp.*), goats (*Capra sp.*), cattle (*Bos sp.*), horses (*Equus sp.*) and pigs (*Sus sp.*) have been utilised throughout the time period outlined above, both as wild game and after domestication. Samples of these key species have been used to produce a reference collection to represent European fauna from the Mesolithic through to the early (pre-Roman) Iron Age. Along with these more familiar animals, a number of other species have also consistently appeared both as skeletal elements and in the form of preserved skin items. Red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), moose (*Alces alces*) (elk in Europe) and reindeer (*Rangifer tarandus*) were an important source of meat and goods (Barker, 1999; Harding, 2000; Legge and Rowley-Conwy, 1988; Whittle, 1996). Fur bearers such as bear (*Ursus arctos arctos*), badger (*Meles meles*), beaver (*Castor fibre*), lynx (*Lynx lynx*), hare (*Lepus europaeus*), fox (*Vulpes vulpes*), pine marten (*Martes martes*), wild cat (*Felis silvestris*) and wolves (*Canis lupes*) are also in evidence at many sites across Europe (Barker, 1999; Harding, 2000; Harris, 2009; Charles, 1997; Fairnell, 2007b; Fairnell and Barrett, 2007a; Howard-Johnston, 1998; Rowley-Conwy, 1995b; Groenman-van Waateringe, 1999). Domestic dogs also make a frequent appearance in the faunal record. Samples of these key species will be used to produce a reference collection to represent Europe from the Mesolithic through to the early Iron Age.

Animal exploitation varies considerably across Europe, both spatially and temporally, though some general tendencies do exist. One is the apparent focus on big game during much of early prehistory, though small game also had its place in the economies of prehistoric Europe and appears consistently in the faunal record through time. Small game provides an important source of fat and protein bridging the inevitable gaps between successful hunts for larger game and was perhaps targeted for its durable, warm and aesthetically pleasing furs. After the adoption of herding in the Neolithic, the dominance of large herbivores in the faunal record is more pronounced. A trend which continues through the subsequent Bronze and Iron Ages.

The second and perhaps the most significant trend is the dramatic decrease in the dependence on wild game over time, which was replaced almost entirely in many areas by domestic livestock (Boyd *et al.*, 1964; Greenfield, 1991; Larson *et al.*, 2007; Larsson, 1990; Rowley-Conwy, 1995c; Sharples, 2000; Whittle, 1996).

The third is a geographic trend as to which species of animals the economy was based on. The Southern parts of Europe and the Middle East can be generalized as having an economy based more heavily on sheep and goats when compared to Northern Europe, where the economy showed a general tendency to favour cattle rearing (Halstead, 1992; Payne, 1973; Ryder, 1983; Hesse, 1982; Larson, 2011; Götherström *et al.*, 2005; Loftus *et al.*, 1994; Rowley-Conwy, 1995c; Whittle, 1996; Harding, 2000). This generalization of course varies by site and location, with pigs and wild species making up a significant portion of the faunal material at many sites. Sheep increased in significance in the late Bronze Age in northern Europe, perhaps as a response to more land being cleared for farming (Harding, 2000; Higham, 1968; Russell, 2012).

Mesolithic

During the Mesolithic, prior to the domestication of animals other than dogs, hunting, trapping or scavenging were the available options for procuring meat. Faunal analysis of various sites across Europe from this time period shows that the predominant prey-species were reindeer, horse (*Equus sp.*), red deer, roe deer, wild boar (*Sus scrofa*), moose and aurochs (*Bos primigenius*). Also present were domestic dogs (*Canis lupes familiaris*) and fur-bearers such as foxes, wolves, lynx, bears, beaver, pine marten, wild cat, lynx and badgers (Andresen *et al.*, 1981; Barker, 1999; Legge and Rowley-Conwy, 1988; Whittle, 1996; Charles, 1997; Fairnell and Barrett, 2007a; Richter, 2005). For clarification before further discussion on species, the term Elk refers to a different animal in North America than in Europe. *Alces alces* are known as 'moose' in North America, whereas in Europe they are called elk. The species referred to as 'elk' (*Cervus canadensis*) in North America are very similar to red deer (*Cervus elaphus*) – similar enough that they can interbreed. Since all three animals are sampled in this project clarification is necessary. 'Moose' will designate (*Alces alces)*, red deer will apply to (*Cervus elaphus*) and 'elk' will refer only to (*Cervus canadensis)*.

The Bos and Equus families have solid hair shafts and as such have coats which when used as a fur are more resistant to wear than the Cervid family. Cervids have hollow hair shafts which are more brittle than solid hair shafts. This causes the hairs to break off more easily when used as a fur. This trait is also true of reindeer; however, their skins are heavily used ethnographically despite this short coming as they are densely haired, very warm and available in large numbers in arctic regions. The niche requirement of highly thermally effective clothing needed in cold climates was likely, at least in part, filled by hunting carnivores and fur bearers, which possess fur far superior to most ungulates in terms of durability but not necessarily in warmth, though exceptions such as muskox (*Ovibos moschatus*), Bison (*Bison bison*) and yak (*Bos mutus*) certainly exist. Smaller carnivores and furbearers do not make up a large portion of the dietary regime at most sites however, they are still present at most sites and have to be considered as a part of the prehistoric economy (Charles, 1997; Fairnell and Barrett, 2007a; Richter, 2005; Strid, 2000).

There are, within the large prey species, significant differences in the characteristics of their skins. A notable example is wild boar, whose thick tough skin is very difficult to de-hair, de-flesh and de-grease using methods available to prehistoric groups. This leads the author to suggest that this species may well have been used only for rawhide applications such as lacing, containers and over shoes. The dominance of large game supplemented with small game, carnivores and various furbearers holds true for a wide variety of sites as far flung as Riparo Contineza in Italy, Star Carr in Britain and Hjerk Nor in Denmark (Strid, 2000; Barker, 1999; Charles, 1997; Rowley-Conwy, 1995b), and continues to be seen in the faunal record over the succeeding millennia.

Neolithic

Beginning in the Neolithic, sheep, goat, cattle and pig become the dominant faunal type, represented across Europe (Whittle, 1996; Budiansky, 1999). In the southern parts of Europe specifically France and Spain, sheep, cattle, goats and pigs are documented by approximately 6000 BC (Rowley-Conwy, 1995: 346). These domesticates appear in the faunal record of central and western Europe by 5000 BC (Whittle 1996: 157). Domesticates quickly expand to become the dominant faunal types, represented across Europe by the mid Neolithic in most areas and by about 4000 BC in the more peripheral Northwest such as Britain and Scandinavia (Budiansky, 1999; Russell, 2012; Whittle, 1996).

Though domestic animals begin to dominate the faunal record in the Neolithic, wild game by no means disappears. Red deer, roe deer and aurochs skeletal elements are still found in many sites, often alongside their domesticated kin (Halstead, 1987, Halstead, 1992, Whittle, 1996, Russell, 2012, Barker, 1999). Davis (1987: 140) postulates that the continued reliance on hunting at many sites may reflect a fluctuating success rate for early herders during the initial domestication process.

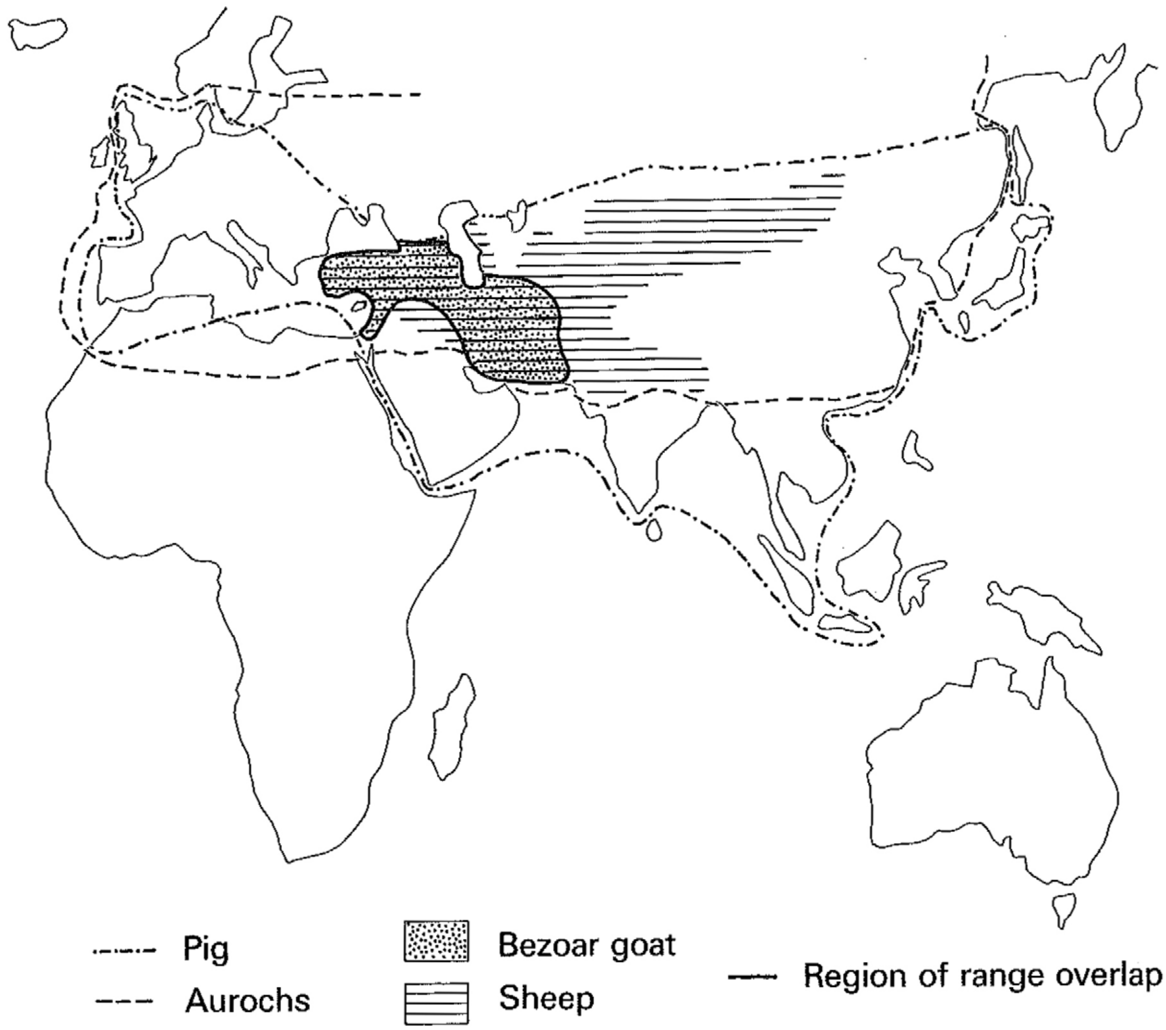


Figure. 3.2-1. Original Distribution of Wild Pig, Aurochs, Bezoar goat and Asiatic Mouflon. (Davis 1987: 128).

Copper Age

This mixed-use economy continues into the Copper Age and is well-illustrated by the famous 'ice man' find on the Austrian-Italian border. Ötzi, an approximately 5000-year-old, naturally mummified traveller, died whilst wearing clothing and carrying gear constructed from both wild and domesticated species (Spindler, 1994: 229; Egg *et al*, 2009). Other finds from glacial sites similar to Ötzi highlight the fact that he and his accoutrements were typical for his era though perhaps designed especially for high alpine travel, not necessarily everyday life at lower elevations, and were a product of unusual preservation, not a person of unusual status (Barber, 1991; Pinhasi *et al.*, 2010; Spangenberg *et al.*, 2010, Schlumbaum *et al.*, 2010; Hafner, 2012). This evidence highlights that both domestic and wild species were important to past economies and as such, are also important additions to the sample collection

Bronze Age – Early Iron Age

The use of wild game alongside domestic livestock is apparent throughout the Bronze Age. Though, during this time period the percentage of wild game shows a significant decrease in importance or availability, perhaps caused by human expansion and land-clearing practices (Harding, 2000). Aurochs, which had been a favourite game animal, disappear in the Bronze Age from many archaeological assemblages. The last well-dated specimen to come out of the UK dates to 1295 BC (Davis, 1987: 179), though Aurochs persisted into historical times in small pockets of protected forest in Eastern Europe (Nowak, 1991). Also notable during the Bronze Age, is the introduction of the domestic variety of the horse into Europe, and with it a new subset of skin items in the form of tack (Harding, 2000: 171; Davis, 1987: 134).

Most of the famous Iron Age bog finds from Denmark have been wearing skins of domestic animals, but there are a few sites that still contain the remains of wild animals, most notably red and roe deer, and occasionally wild boar (Hald, 1980; Mannering *et al.*, 2010; Gleba and Mannering, 2012). This dramatic decline in the occurrence of wild faunal remains in Early Iron Age sites would continue through successive generations until wild species became a rare find in faunal collections, in all but the most remote parts of Europe, or as an elite dish, available only to those owning large forest preserves for private hunting (Davis, 1987; Albarella, 2010).

Continental and Regional Significance

All of the species chosen from the European region were historically found over the entirety of the region. The progenitor species for domestic sheep and goats, the Asiatic Mouflon (*Ovis orientalis*) and the Bezoar goat (*Capra aegagrus*), were available as wild game over large areas of the Near East and for the Mouflon the eastern side of Europe as well (Figure. 3.2-1) (Nowak, 1991: 1484; Davis, 1987: 131).

Cattle and pigs, however, were native to Europe in the form of aurochs (*Bos primigenius*) and wild boar (*Sus scrofa*), and though originally domesticated in the Near East, herds were later supplemented with local stock. Based on genetic testing, it is apparent that once the techniques and technology required for domestication were understood, wild aurochs and boar were captured not just for meat but for bolstering the numbers of local domesticated herds (Götherström *et al.*, 2005; Larson *et al.*, 2007).

Horses, absent from the archaeological record for 3500 years, reappear in small numbers in Northern and Central Europe approximately 3000 BC though their status as domesticated livestock at this time is unclear. By 2000 BC they are regular finds in the faunal material (Sherratt, 1983; Outram *et al.*, 2009; Bendrey, 2012; Bendrey *et al.*, 2010). This hiatus was likely caused by the severe climate changes at the end of the last ice age, which saw horses become extinct outside the Eurasian plains, steppe and in Iberia (Jansen *et al.*, 2002). Prior to this extinction, horses roamed large parts of Europe and the British Isles.

Red deer and roe deer have been present in Europe consistently since the before the last ice age. They were the cornerstone of Mesolithic hunting communities and are present in the majority of sites across Europe through the Early Bronze Age, and in a few sites as late as the medieval period (O'Connor, 2010; Sharples, 2000; Davis, 1987; Legge and Rowley-Conwy, 1988; Rowley-Conwy, 1995b).

Overview of the Archaeological Evidence

Faunal Presence in Archaeological Sites

The faunal evidence for a project covering the geographical and temporal scope outlined for this research is vast. Due to this it is more applicable to discuss this aspect on a species by species basis and will be addressed in the individual species sections which follow.

Processed Skin Finds

In 1991 the find of a prehistoric naturally mummified hunter, dubbed Ötzi, garnered worldwide interest. Radio carbon dated to 3350-3100 BC, Ötzi was more than just a body, as preserved with him were many of his personal effects, including items made from animal skin. His shoes had bear skin soles with the fur turned inside, with hair-on deer skin uppers; his leggings, originally thought to have come from deer, ibex or chamois, have recently been identified as sheep using protein analysis. He wore two belts, both of which were made from depilated calf skin, and a breech cloth which was most likely goat skin (though sheep could not be completely ruled out). He wore a cap of brown bear fur and carried a quiver made from hair on skin, which could have belonged to deer, ibex or chamois. A belt bag made from depilated calf skin was found with him, as well as various pieces of leather thong (Spindler, 1994: 229; Hollemyer *et al.*, 2008; Egg *et al.*, 2009: 83).

Though the 'Ice man' find is arguably the most famous glacier find, it is by no means the only find from this time period. At Schnidejoch Pass in the western Swiss Alps, over 300 leather artefacts were recovered from 2003 to 2009, when the glacier in which they had been encased began to retreat due to warmer conditions. Objects discovered include hunting gear, shoes, various pieces of fur and leather, woollen items and coins. The earliest of these finds date to the late Neolithic, including a large piece of leather identified as a legging, and radiocarbon dated to 2914-2652 cal. BC (Spangenberg *et al.*, 2010; Hafner, 2012; Schlumbaum *et al.*, 2010). Another ice patch find dating to the Iron Age was discovered in 1992 near Bolzano/Bozen-Italy. The find consisted of two large pieces of processed skin, and a number of smaller fragments including some preserved seams, which are parts of skin footwear (Bazzanella, 2005).

The Bronze Age provides a steady increase in the amount of preserved skin artefacts. Armour, horse tack, plough equipment, and skin items from intentional burials, salt mines, retreating glaciers and bogs have all survived in various Bronze Age sites (Harding, 2000; van Driel-Murray, 2000). In the Hallstatt salt mines of Austria, large amounts of skin artefacts have been recovered. 90% of these items were constructed using skins from domestic species, including cattle, goats and sheep. The remaining 10% have been identified as wild Chamois/Gemse (*Rupicapra rupicapra*) or Steinbock (*Capra ibex*), as well as dog and other small fur-bearers (Popa and Kern, 2009: 105) There is evidence that the salt deposits were exploited as early as 5000 BC during the Neolithic. However, intensive mining began during the Bronze Age, and these mine galleries were in use by 1400 BC at the latest (Reschreiter, 2005). Besides the Bronze Age north group, there is a Late Bronze Age (1260-1020 BC) component to the East group. The East group also contains galleries from the Early Iron Age (Hallstatt period 800-400 BC). The West group dates from the La Téne period (Iron Age) to the Late Roman (110 BC-240 AD) (Harris, 2009; Reschreiter, 2005).

Numerous processed skin finds have been recovered from peat bogs across northern Europe. (Hald, 1980; Mannering *et al.*, 2010; Goubitz *et al.*, 2001). They include shoes, capes, bags and various scraps of skin many of which are beautifully preserved. This preservation is product of sphagnan a chemical produced by sphagnum moss, interacting with the tissue's proteins (Covington, 2011: 455). Though there is some concern that these items have been secondarily vegetable tanned, therefore limiting the information to be gained concerning tannage type (see In-Life Use Traces chapter 7), they still provide a nearly unparalleled collection of organic artefacts documenting daily life in these areas.

Genetic Research

The role of genetics in interpreting archaeological finds has become increasingly important over the last 20 years, as the analysis has become less expensive, and the results more precise and more quickly achieved (Bradley, 2006a; Lalueza-Fox, 2013). It has been used to identify the species of origin for numerous skin items (Spangenberg *et al.*, 2010; Spindler, 1994; Luo *et al.*, 2011), to date the initial domestication of animals, to identify and separate domestication events by region, note geographic trends in genetic diversity, investigate genetic responses to domestication, and look closely at individual genes which have significant impact on prehistoric animal and human interactions such as genes relating to lactose tolerance in humans (Fernández *et al.*, 2006; Hiendleder *et al.*, 1998; Jansen *et al.*; 2002, Larson, 2011; Larson *et al.*, 2007; Loftus *et al.*, 1994; Beja-Pereira *et al.*, 2003). The majority of this research is carried out on Mitochondrial DNA (mtDNA) and Y chromosomes (the sex chromosome which is normally only present in male cells) which make up a haplotype. 'A haplotype is a package of genetic material that incorporates multiple variable sites or markers, and which can be considered as a unitary, heritable package that is uncomplicated by recombination through the generations' (Bradley 2006: 273). Genetic research was used to support species selection based on skin finds, which have been genetically analysed to identify the species of origin. The same field has been used to more strongly support a link between a modern unimproved breed and its Neolithic or Bronze Age predecessors, supporting the choice for inclusion in the comparative sample collection.

Rock Art and Associated Artefacts

Though not directly diagnostic in and of themselves, artistic representations provide interesting circumstantial evidence of animal exploitation, and provide further support for the inclusion of certain species in the sample collection. These representations come in many forms, from the cave paintings of the Palaeolithic to rock carvings in the Neolithic and Bronze Age showing fields of cattle, and sheep and cattle pulling ploughs (Barfield and Chippindale, 1997). Pottery cart and yoke figurines show up in several parts of Europe around 3500 BC supporting the use of cattle for transport and traction (Barker, 1999; Davis, 1987: 163). There are also some examples of surviving yokes found at Lovagnone and Fiave which date to the Early to Middle Bronze Age, and a yoke from Loch Nell, Argyll dated to 1950-1525 cal. BC (Harding, 2000: 128). Further evidence for the importance of cattle comes from an Uruk period cylinder and two seals one from Iraq (c. 2500 BC), and another from Knossos from the late Bronze Age (Evans, 1935), all showing cattle being milked.

A sheep figurine from Tepe Sarab with surface decoration of even downward facing chevrons has been interpreted as representing staples of medium hairy wool (Sherratt 1983 citing M.L. Ryder pers. comm.) indicating that sheep were being selected for wool, as well as milk and meat as early as 6000 BC (Bokonyi, 1974). This change from short haired to longer haired varieties of sheep at such an early date has implications for selecting variety.

Other associated artefacts from the Italian Copper Age which highlight the importance of these new products are spindle whorls and ceramic sieves (Wilkens, 1991 in (Barker, 1999), like those used today for cheese making and hand spinning yarn.

Evidence for Choosing Variety

An important concern when evaluating domestic animals for inclusion in the sample collection was to find a variety which resemble their Neolithic ancestors. This continuity in breed type or variety is necessary to improve the relevance of the sample collection to archaeological collections. This section will detail the attributes which were considered when choosing a breed for each domesticated species.

Size

One of the hallmarks of an unimproved breed is often a smaller size than many of our modern breeds. This is especially true of cattle and horses whose predecessors were significantly smaller than today's standards (Bendrey *et al.*, 2010; Bendrey, 2012; Rowley-Conwy, 1995c). Metrical analysis from numerous sites gives us a fairly good idea of the average size of each species during the time frame encompassed by this project. Details of size variation over time, and to what degree it influenced breed selection, will be expanded upon in the following individual animal sections.

Hair/Coat type

The change in coat type through time is linked closely to the evolution of domesticates, most notably with sheep, but also as an (likely) unintentional by product of cattle, pig, horse and to some degree goat breeding. Most wild animals have two distinct coat types, under fur and guard hair (Ryder, 1964; Harrison, 2002; Leon Augustus, 1920; Ryder, 1980) This applies to wild boar as well, who boast a downy under coat covered by the characteristic bristly guard hairs we now associate with boar bristle hair brushes. Cervids would seem to be the exception, but when the coat thickens noticeably in winter there are finer hairs which differ dramatically from the outer coat. Hair shaft diameter has been used in the analysis of archaeological finds of cattle and sheep hair and fur (Ryder, 1964; Ryder, 1981; Leon Augustus, 1920) then compared to today's breeds to chart the change in diameter through time. Sheep are of special note here of course, as they have undergone significant change in the character of their coats over time, having changed colour, lost the ability to moult naturally and developed a coat comprised solely of underfur. Where there is enough information about coat development to inform the breed selection process, it will be covered in the individual animal sections.

Genetics

Genetics plays a role in breed selection based on geographic variation of haplotypes. If haplotypes found in archaeological sites known to be in the area of initial domestication for a species show up in Britain, for example, then the breed carrying that haplotype has a direct genetic link to the progenitor groups. This ability to trace these haplotypes allows modern breeds to be traced to their most likely geographic origin. The known rate of divergence for these relatively stable genetic markers can also give information on the time depth of specific haplotype groups, allowing researchers to note divergences which happened prior to, or after domestication, though this tool reaches its limit when trying to calibrate finer divergences within haplotype clusters (Bradley, 2006: 275). These genetic markers when combined with other evidence helped identify breeds which may be closely related to their prehistoric predecessors (Campana *et al.*, 2010; Hiendleder *et al.*, 2002; Jansen *et al.*, 2002; Larson *et al.*, 2007; Loftus *et al.*, 1994; Luikart *et al.*, 2006; Miika Tapio, 2006). It is acknowledged that at the time of the initial research for assembling the sample collection, whole genome sequencing was still very new. As such it was not included in the original considerations. If applicable, mention is made of this newer material in the individual species sections.

Breed Rosters

This line of evidence is more modern in origin, but in some cases can be used to trace a breed as far back as the 1300s. It can also be used to discount a breed which looks like an unimproved breed but was actually bred for those characteristics quite recently – for example, the Heck cattle bred by the Heck brothers in Germany in the 1920s and 1930s to closely resemble the Aurochs phenotype. A more scientific program in the Netherlands is attempting to recreate the Aurochsen genotype through an intensive back breeding program and possible cloning of extant DNA from archaeological samples (Taurus, 2012).

Conclusion

The above is an overview of the parameters for the selection of species and, within species, breeds. For each of the choices there are more detailed arguments to be made, which have been organised into the regional zones of Europe and North America, for clarity's sake. The two bodies of literature between Europe and the North America tended to be separate traditions of scholarship, with different trends in research. For example, the origins of domesticates is a major research trend in European prehistory, which is not mirrored in North America. The latter instead focuses on major changes, such as the extinction of the mega fauna at the end of the last ice age, Holocene climate change and later the reintroduction of animals such as the horse and sheep, which in some areas drastically change how the landscape is utilised by its inhabitants. In order to maintain comparability, a systematic approach to each species has been adopted by means of standardised subheadings, including: physical characteristics, prehistoric and modern range, habitat preference and behavioural characteristics, hunting strategies and/or slaughter patterns, domestication, prevalence in the archaeological record, genetic research, and finally, the feasibility of sourcing the skin.

3.3 European Faunal Selection

The following section details the selected species on an individual basis.

Wild Species

Red Deer (*Cervus elaphus*), Roe Deer (*Capreolus capreolus*), Fallow Deer (*Dama dama*)

Name:	Red deer (*Cervus elaphus*)	
Physical Characteristics:	Sexual Dimorphism: Males are usually heavier than females.	
	Males	**Females**
Weight:	90-190kg (198-419lbs)	63-120kg (139-265lbs)
Pelage:	Typically, reddish to dark brown with a lighter off white to yellowish belly. The males develop dark thick manes during the rut which stay with them until the spring moult. (Nowak, 1991; Darling, 2008; Macdonald and Barrett, 1993; Southern, 1991)	

Name:	Roe deer (*Capreolus capreolus*)	
Physical Characteristics:	Sexual Dimorphism: Males only slightly heavier than females.	
	Males	**Females**
Weight:	10-25kg (22-55lbs)	10-25kg (22-55lbs)
Pelage:	Summer coat is reddish brown turning to greyish brown during the winter (Nowak, 1991; Macdonald and Barrett, 1993).	

Name:	Fallow deer (*Dama dama*)	
Physical Characteristics:	Sexual Dimorphism: Males are usually heavier than females.	
	Males	**Females**
Weight:	46-80kg (88-176lbs)	35-52kg (77-115lbs)
Pelage:	Variations in this species range from white, to nearly black. The most common coloration is a fawn summer coat with white spots on the back and flanks. The winter coat is greyer, and the spot are absent, or at least less distinct. (Macdonald and Barrett, 1993; Nowak, 1991).	

Roe (*Capreolus capreolus*), red (*Cervus elaphus*) and fallow (*Dama dama*) deer were extensively hunted throughout prehistory, and, though their economic importance as a meat source diminished with the introduction of domestic livestock, it was never completely replaced.

Physical Characteristics

Red deer are the largest deer other than moose (*Alces alces*) in Europe. Stags or bucks have annually shed antlers with up to 16 points (tines) in total. (Nowak, 1991; Darling, 2008; Macdonald and Barrett, 1993; Southern, 1991)

Roe deer are the smaller of northern Europe's five native deer species. The bucks grow short antlers with three tines on each beam, which are shed annually (Nowak, 1991; Macdonald and Barrett, 1993). An additional roe deer adaptation is delayed implantation of fertilised eggs. Mating occurs in August, but the egg does not implant nor grow until January (Nowak, 1991: 1400).

Fallow deer fall between roe and red deer in size. As with most deer, the males grow and shed a set of antlers annually. However, unlike roe or red deer, fallow antlers are palmate with numerous points except for two-year-old males which instead grow a set of single unbranched tines. (Macdonald and Barrett, 1993; Nowak, 1991).

For Reindeer (*Rangifer tarandus*) and Moose (*Alces alces*) see Transcontinental Species.

Prehistoric and Modern Range

Roe, red and fallow deer are present in faunal assemblages across Europe, with their numbers at the highest during inter-glacial periods. They were present in what is today the United Kingdom (UK), in conjunction with evidence of human industry as early as 250,000 years ago, during the Hoxnian and later during the Ipswichian inter-glacial periods. The faunal assemblages from these early periods come from the sites of Hoxne, Clacton and Swanscombe (Davis, 1987: 170). Roe and red deer repopulated the northern areas of Europe naturally during the Late Glacial period, where Fallow deer remained a southern species until widespread intentional reintroductions established large populations across Europe. The Romans are thought to have reintroduced fallow deer to the UK as a trophy animal (Southern, 1991; Macdonald, 2005).

Over-hunting of red deer in Britain eventually decreased the numbers, until only remnant populations existed in South West England, the Scottish Highlands, and a few other isolated pockets. Reintroductions during Victorian times, combined with habitat improvement, have allowed red deer to reclaim much of their native territory. Interestingly, some North American Elk (*Cervus canadensis*) were used to replenish the stock in the United Kingdom. There is a distinct difference in size between the two subspecies, with the North American variety being significantly larger (Kuwayama and Ozawa, 2000; Nowak, 1991: 1373).

Roe deer saw a steep population decline and eventual extinction in the UK by the 1800s. This was due to land-clearing practices, which created areas of grass that browsers such as roe deer cannot efficiently consume. Reintroductions during Victorian times and twentieth century forest reclaiming have helped roe deer once again become widespread in Britain. Populations on the continent have stayed more stable, perhaps due to larger tracks of intact woodland (Nowak, 1991: 1374).

Habitat Preference and Behavioural Characteristics

Roe deer prefer woodland habitat and are mostly solitary. They will sometimes form small groups during winter months when forage is scarcer (Nowak, 1991; Macdonald and Barrett, 1993).

Red deer are more comfortable in open areas than roe deer and are grazers, though they can browse on woody plants when grasses are in limited supply. Red deer migrated to UK from continental Europe at least 11,000 BP. They form small mother and calf groups for the majority of the year, or larger single sex groups in areas of open ground; in the Scottish Highlands very large herds form for much of the year. Red deer are more diurnal than roe deer, but the hours of highest activity are still dusk and dawn (Darling, 2008; Nowak, 1991).

Hunting Strategies

Roe deer are solitary, crepuscular (active at dusk and dawn) animals and would have been difficult to acquire using any mass capture techniques. This behavioural pattern lends itself more to hunting individual animals or trapping (British Deer Society, 19/3/11).

Red deer's tendency towards larger herds, more diurnal habits, and a larger meat return per animal, make them a desirable prey species. While definitely hunted singly, it is also possible that they were hunted in drives or by other mass capture techniques.

Fallow deer prefer a diurnal pattern but, in areas of disturbance, they are crepuscular, with older males leaning toward nocturnal (Southern, 1991; Macdonald, 2005). As with red deer, their social behaviour of same sex group formation for most of the year lends itself to mass capture techniques such as drives and large-scale pit traps. Hunting and trapping of individual animals were undoubtedly practised as well.

Prevalence in the Archaeological Record

Some sites which highlight the importance of deer through time include Star Carr, the early Mesolithic site in Yorkshire (9500 BP), in which a large percentage of the site's faunal remains are roe and red deer, and the late Mesolithic site of Morton Tayport in Fife, Scotland (6432-6165 BP), where the preponderance of faunal material consisted of ungulate remains (Andresen *et al.*, 1981; Bratlund, 1996; Mulville, 2010; Pitts, 1979; Sharples, 2000; Davis, 1987).

In the Neolithic, domestic animals dramatically over take wild game as the most important meat source, but early Neolithic sites on the continent such as Grotta del' Uzza in Sicily, Noyen-sur-Seine in Northern France, the Friesack site Northwest of Berlin and the Danube Gorges between Serbia and Romania all have more deer remains than domestics. The Tyrolean Ice man, dubbed Ötzi, wore deerskin and dates to c. 5350-5300 cal. BP (Whittle, 1996; Egg *et al.*, 2009).

During the Bronze Age, reliance on wild game decreases even further, as more land is cleared for agriculture and domestic livestock. However, sites continued to show a small percentage of wild game utilisation. A few Bronze Age sites with large percentages of wild game remains include West Fen Row in Britain (5%), Dres den-Coschutz in Germany (18%), Bekes-Varoserdo in Hungary (25%), Ljuljaci in Romania/Serbia (42%, 15% of which was red deer), Pitigliano in Italy (37%) and Fuente Alamo LBA in Spain (39%) (Harding, 2000: 139).

This trend towards domestics dominating the faunal record continues through the Iron Age, though, moving into the Medieval, large numbers of deer bones in many castle sites are evidence that deer are still a valuable meat source, though perhaps more of an elite dish. Roe, Red and Fallow deer remains appear in large numbers over a wide geographic area and were utilised from the Palaeolithic through to modern times, making them an important choice for inclusion in this project.

Genetic Research

Red, Roe and Fallow deer are little changed today from their Palaeolithic counterparts, making this research of little relevance to these species with regards to choosing a variety for the reference collection. There is some interesting genetic research looking at the level of kinship between the North American Elk (*Cervus canadensis*) and the European Red deer (*Cervus elaphus*), which states that, although they are very closely related, they are indeed deserving of the status of separate species. This, the size difference between the two varieties, and the vast distance between their habitats was enough to warrant the inclusion of both in the reference collection (Lowe and Gardiner, 1989; Polziehn and Strobeck, 1998).

Feasibility of Sourcing Skin

The skins of red, roe and fallow deer are readily available due to herd culling on private land and were sourced from a local game processing operation.

Domestic Species

Pig (*Sus scrofa domesticus*)

Domestication and Prevalence in the Archaeological Record

The domestication of pigs, as with most other domestic species, is thought to have first occurred in the Near-East, between 11,000 and 10,000 BP (Albarella *et al.*, 2006; Larson, 2011; Larson *et al.*, 2007; Larson *et al.*, 2005; Albarella, 2010; Vigne *et al.*, 2011). Unlike sheep (*Ovis aries*) and goats (*Capra aegagrus hircus*), whose non-native status in Europe during the Holocene and subsequent recovery from European archaeological sites directly implies their introduction from the Near East, wild boar (*Sus scrofa)* were and still are widely distributed from Europe to Eastern Asia.

The first decisive evidence for domestication of wild boars is a rapid decrease in size, seen at Neval Cori in the upper Euphrates river basin. This size decrease is indicative of constant and intensive breeding pressure (Vigne *et al.*, 2011; Vigne *et al.*, 2009). Prior to domestication wild boar are frequent finds in Mesolithic sites – for example, the sites of Thatcham and Faraday Road in the UK (Albarella, 2010). The faunal remains are also well represented across Europe for this period, as well as for the Neolithic, though at this point wild boar become elusive in the archaeology with the introduction of domestic pigs. Whether this is due to a drop in the hunting of wild boar or simply a difficulty in distinguishing between wild and domestic animals is unclear (Albarella *et al.*, 2006; Larson *et al.*, 2007).

Genetic Research

Extensive MtDNA sampling of both ancient and modern pig remains, as well as of local wild boar, has helped to shed light on the original domestication of pigs, and subsequent introduction of pigs and pig herding knowledge into Europe. DNA analysis has helped to inform what role native European wild boar played in the development of today's domestic pig breeds. Out of 478 samples from 140 archaeological sites spanning 13,000 years, eighteen different haplotypes were identified. (Haplotype is a group of alleles of different genes (as of the major histocompatibility complex) on a single chromosome that are closely enough linked to be inherited usually as a unit (Inc., 2004) These eighteen haplotypes grouped into four geographically specific clades, two Near Eastern, two European. Of the two European clades one was a minor clade endemic only to Italy. The Near Eastern haplotypes appear to extend to the North shore of the Black sea, based on wild specimens collected from Mesolithic and Neolithic Crimean sites (Larsen *et. al.*, 2007).

These Near Eastern haplotypes were found in eleven specimens from Neolithic Romanian sites by approximately 7500 BP, Linearbandkeramik (LBK) sites in Northern Germany by the 6th millennium BC, and in samples from the very early 4th millennium Paris Basin site of Bercy (Larsen *et. al.*, 2007). Bercy is the latest site to possess domestic pigs with a Near Eastern haplotype, and the only site in this study where definitively domestic pigs with both European and Near Eastern haplotypes coexisted. All samples taken from the UK and mainland Europe from the 4th millennium through to present day are comprised exclusively of European haplotypes. This indicates that in response to Near Eastern livestock introductions, native European inhabitants were domesticating local wild boar populations. In only 500 years, the European haplotypes went from comprising 5% of the population to 95% of the population. These European haplotype populations were introduced back east to Armenia, where they completely replaced the indigenous population by the 7th century BC (Larsen *et. al.* 2007).

This secondary domestication of European wild boar may not have been as dramatic a leap of domestication technology as it first appears. There is significant evidence of herd management of wild boar in Europe 1500 years prior to their generally accepted time of introduction from the Near East (Vigne *et al.*, 2009). The level of intensity of this herd management is contentious, but the introduction of pigs onto the island of Cyprus by humans as early as 12,000 years ago supports its existence. If these suids were being ferried across large stretches of open water to intentionally populate an island, it stands to reason that some more specialised relationship than hunter and hunted had also developed between humans and wild boar on the mainland (Vigne *et al.*, 2011; Vigne *et al.*, 2009).

Progenitor Species

The wild boar (*Sus scrofa*) has certainly contributed much of its genetics to the domestic pigs of today as evidenced by the previous section. The likelihood that the early domestic pig's skin and coat closely resembled a wild boar then stands to reason.

Physical Characteristics

Wild boar (*Sus scrofa*) have a compact powerful body shape, with short stocky legs and a large head. They are covered in a dark bristly pelage and develop a dense undercoat in the winter months. Males grow large upward pointing canine teeth and range in height at the shoulder from 64-109 cm (2-3.6 ft), and range in weight from 33-108 kg (73-238 lbs). Females are smaller with a shoulder height from 59-89 cm (2-2.9 ft) and weighting from 30-80 kg (66-176 lbs). Females produce an average of 4-7 young with horizontal stripes which fade between 3-5 months of age. Both males and females are strongly scented (Nowak, 1991: 1338; Macdonald and Barrett, 1993: 197).

Prehistoric and Modern Range

Wild boar were widespread in all of Europe including the UK during the upper Paleolithic and Mesolithic, but began to dwindle in the UK during the Neolithic. However, there remained strong populations elsewhere in Europe throughout this period. The Medieval period saw a further decrease in numbers of wild boar across Europe, but especially in the UK, where it was officially hunted to extinction by end of the thirteenth century. Attempts at reintroduction for hunting ended in the seventeenth century, and it remained absent from the British Isles until its accidental reintroduction when escapees from wild boar farms formed feral populations in some areas of south western Britain. Southern Sweden is a second area of Europe where only remnant populations remain. Other areas of Europe, such as many areas in Germany and Eastern Europe, boast healthy wild populations (Albarella, 2010; Macdonald and Barrett, 1993).

Habitat Preference and Behavioural Characteristics

Wild boar are omnivorous and prefer deciduous woodlands, open meadows and farmland. They are mainly crepuscular and nocturnal and in some areas of Europe show seasonal preference for woodlands through the winter months, but open farmland during the warmer season. Females tend to form groups and travel with their young, and only associate with mature males during the breeding season. Males fight with other males for the right to breed and average between 1 and 3 females a season, with very successful males managing to win over up to 8 females (Nowak, 1991: 1338; Macdonald and Barrett, 1993: 197).

Relevance of Breed Selection

The localised nature of pig domestication (pigs do not herd well over long distances) and lack of research concerned with primitive breeds have hindered the selection of a breed representative of Neolithic pig types. This is offset by the survival of the progenitor species. Wild boars exist as a non-endangered, locally acquirable species and will be used as the Sus species sample for this project.

Feasibility of Sourcing Skin

Wild boar are routinely raised as a food animal as well as, occasionally being culled from forested reserves around Britain therefore acquiring a skin is reasonably easy. The skin was sourced from the Real Boar Company in Chippenham, Wiltshire.

Sheep (*Ovis aries*)

Domestication and Prevalence in the Archaeological Record

Sheep were one of the earliest animals domesticated for agricultural purposes, and, as a provider of multiple products, are one of the most important domesticates (and based on geographic coverage and population, arguably the most successful). Domestication of wild herds began as early as 12,000 cal. BP, based on the north western Zargos site of Zawi Chemi Shanidar, with solid faunal evidence from 10,500 cal. BP onwards at Near Eastern site of Nevali Cori (Zeder, 2011). These original sheep would have had a coat comprised of outer coarse guard hair, with a soft fine undercoat or fleece, which they shed annually. Most modern breeds have very little guard hair or 'Kemp' left, having been bred for thousands of years to produce a longer, finer and thicker coat, comprised almost exclusively of the fleece hairs. Modern breeds no longer shed annually and are dependent on humans for shearing (Boyd et al., 1964; Ryder, 1964; Ryder, 1983: 45).

A clay miniature dated to 5000 BC, found the Sarab site in Iran, shows a sheep with what can be interpreted as a woolly coat, indicating that this coat type was being selected for very early on (Ryder, 1983: 52). Some Mesopotamian and Babylonian art from 5000 BP show sheep similar in appearance to modern animals (Department of Animal Science, 2008). Though these animals appear similar, it is likely that they were a breed with a coat in between the modern shearable, woolly coat and the short hairy coat of wild sheep. This coat type required plucking or "rooing" to harvest the furry under coat while leaving behind the longer coarser kemp, or guard hairs. It could also have been harvested from the ground as it was shed in the spring (Ryder, 1964; Ryder, 1981; Hollemeyer *et al.*, 2008).

Direct evidence in the form of processed skin artefacts made from sheep skin has been recovered from the Halstatt Salt mines (Popa and Kern, 2009: 105; Reschreiter, 2005; Harris, 2009), Northern European bog bodies and coffin burials (Hald, 1980; Mannering *et al.*, 2010; Gleba and Mannering, 2012) and glacial finds in both the Alps and Norway (Egg *et al.*, 2009; Hollemeyer *et al.*, 2008; Schlumbaum *et al.*, 2010)

Progenitor Species

The surviving six species of wild sheep are scattered across Western North America, Asia and the Near East. Genetic testing of these species indicates that the wild mouflon (*Ovis orientalis*) of Anatolia is the most likely predecessor of at least the modern European sheep breeds. The mouflon is the only wild species to share the same karyotype (the chromosomal characteristics of a cell) of 54 chromosomes, as today's sheep. Other wild species which inhabit the Near East are the Urial (*Ovis orientalis vignei*) and the Argali (*Ovis ammon*), which have 58 and 56 chromosomes respectively (Pedrosa *et al.*, 2005; Hiendleder *et al.*, 2002; Bruford and Townsend, 2006.)

Genetic Research

This conclusion is supported by extensive DNA sampling of modern sheep breeds, which showed two maternal lineages: the European mtDNA lineage B, and lineage A found throughout Asia (Hiendleder *et al.*, 1998). Lineage B is closely phylogenetically related to the Mouflon (*Ovis musimon*), which is still found in small numbers in the Near East (Hiendleder *et al.*, 1998; Pedrosa *et al.*, 2005). Pedrosa (2005), after sampling 79 unrelated individuals from various Turkish breeds showed a distinctive third mtDNA lineage C, which diverged earlier than A and B. As these three lineages diverged from one another long prior to domestication, it is probable that today's breeds come from three domestication events, which comprised individuals from different areas (Pedrosa *et al.*, 2005). It is worth noting that the taxonomy of the mouflon has been recently revised and is now *Ovis gmelini* (IUCN/SSC 2000). The mouflon has a number of subspecies, of which the Turkish and Armenian are the most likely ancestors of lineage B, whereas the Estefahan mouflon and the Laristan mouflon may be the predecessor for lineage A (Pedrosa *et al.*, 2005; Hiendleder *et al.*, 2002; Hiendleder *et al.*, 1998). In 2006, a further study identified a very small fourth mtDNA marker (lineage type D), indicating a possible fourth domestication event (Miika Tapio, 2006). In this study 406 unrelated samples from 48 breeds were taken and used to map the percentage of geographical occurrence of each lineage type (Miika Tapio, 2006).

A second line of genetic research undertaken uses the male-specific region of the Y chromosome (MSY) to help support the progenitor species, as well as shed light on introgression from wild male sheep (Meadows and Kijas, 2009). This research showed that large amounts of wild male introgression must have been present, to account for a large percentage of genetic variation shown in the samples. It also supported mouflon as the progenitor species for domestic sheep, as it was the only wild variety to share a haplotype (H6) with modern domestic sheep (Meadows *et al.*, 2006; Meadows and Kijas, 2009).

Relevance of Breed Selection

Some of today's unrefined breeds such as the Shetland and Soay retain many of the characteristics of early domesticated sheep breeds (Ryder, 1964; 1981). Soay, which are characterised by horns in both sexes, a double fleece (an undercoat which sheds annually and a distinct top coat of longer thicker hairs), and short tails, are closely related in size and wool type to their Neolithic predecessors (Ryder, 1964; 1983; 1981; Boyd *et al.*, 1964; Clutton-Brock, 2004). Processed skin artefacts outlined above also support that a sheep with a fleece type similar to that of the Soay were in existence in Europe during the Chalcolithic. Faunal evidence shows sheep similar to Soay had reached the Orkney Islands by 4000 BC (Clutton-Brock, 2004: 17), which indicates that a similar sheep type was already present in the rest of the UK and mainland Europe.

This isolated population shares the mtDNA lineage A (Bruford and Townsend, 2006; Meadows and Kijas, 2009; Miika Tapio, 2006) making it an interesting outlier in the much more common European lineage B, and possibly supporting its status as being little changed since its introduction onto the Orkney's. Feral Soay have survived into the present on the St. Kilda islands located 41 miles off the west coast of Scotland (Boyd *et al.*, 1964). The island of Soay was so named by the Norse, and 'Soay' means 'Sheep Island' (www.soaysheep.com). The Soay's early introduction, long isolation, physiological similarities to early domesticated sheep, and local availability make them the best breed of sheep for inclusion in the sample collection.

Feasibility of Sourcing Skin

Flocks on the isle of Soay, St. Kilda are presumably direct descendants of the first sheep introduced to the islands in prehistoric times. Flocks stemming from them now exist in parks and other islands in Britain. This breed has become popular to those interested in raising rare breeds and a skin was kindly provided by such a breeder.

Goat (*Capra aegagrus hircus*)

Domestication and Prevalence in the Archaeological Record

As with sheep, the epicentre of goat domestication lies in the Near East, the initial domestication of which dates back to between 10,500 and 8600 BP, depending on interpretation of faunal evidence (Fernández *et al.*, 2006; Hesse, 1982; Larson, 2011; Zeder, 2006b). Faunal data from the Tel site of Abu Hureya, in Northern Syria, shows that by 8500 BP sheep and goats account for 60% of the bones recovered. Tooth wear analysis studied the amount of wear present on the milk molars of young animals from the same site, which were kept for approximately one year. The gazelle molars studied from the same site fell into distinct groups of new-borns with very little wear and substantial wear, corresponding to yearling animals. These distinct groups point to seasonal exploitation of the gazelle herds as they migrate North in the spring (Moore *et al.*, 2000). The sheep and goat molars by comparison showed no groupings, suggesting a year-round usage pattern (Budiansky, 1999: 40). Though not proof of domestication, the high percentage of skeletal remains from only two species, combined with year-round utilisation of a normally migratory animal, does support the interpretation that captive herds were being kept at Abu Hureya (Moore *et al.*, 2000).

The site of Arene Candide in Italy contains the faunal remains of goat, which date to approximately 5000 BC. Much farther west, Caldeirao Cave in Portugal contains a substantial portion of domestic animals, with the earliest radiocarbon dates being 4380 ± 80 BC (Rowley-Conwy, 1995a). The first evidence for the presence of goats in the UK comes from Fussell's Lodge in Wiltshire (5240 BP) and Lambourn, Berkshire (5425 BP) (Davis, 1987: 177). Faunal evidence has been found throughout Scandinavia also, though with significantly later earliest dates, some as young as 2220 ± 40 BC (Rowley-Conwy, 1995c; 1995a).

Evidence in the form of preserved skin artefacts has been found in bog contexts (Hald, 1980; Mannering *et al.*, 2010; Gleba and Mannering, 2012), as well as from glacial finds in the Swiss, Austrian and Italian Alps (Egg *et al.*, 2009; Hollemeyer *et al.*, 2008; Schlumbaum *et al.*, 2010; Bazzanella, 2005; Spangenberg *et al.*, 2010).

Genetic Research

Analysis of 2,430 domestic goats' DNA by Naderi, *et al.* (2008) has identified as many as 6 different mtDNA haplotypes: A, B, C, D, F and G. Unlike the binomial matrilineal roots seen in cattle and pigs, goats share with sheep the complexity of having three matrilineal roots, which vastly predate domestication A, B and C. Lineages D, F and G are thought to have developed after domestication. The large amount of mtDNA variation and the distinctive A, B and C groupings lead experts to believe that there were at least 3 captures of wild female goats from geographically or temporally separate groups (MacHugh and Bradley, 2001; Fernández *et al.*, 2006; Luikart *et al.*, 2006; Naderi *et al.*, 2008). 90% of modern domestic goats fall within haplotype A, and it is considered the oldest of the three roots, >9000 years old (Fernández *et al.*, 2006; Zeder, 2006b). B and C are thought to have been introduced into the domesticate population from wild goats, captured later in time from geographically separate areas. A sample of 473 Bezoars from 43 locations produced 221 unique haplotypes, 142 of which can be found in modern goats (Naderi *et al.*, 2008). The C haplotype was the largest group in wild samples but smallest in the modern samples. Both A and C most likely originated in Near Eastern Anatolia, though the C haplotype may have been introduced there by early herders from the central and southern Zargos region to the south-east (Naderi *et al.*, 2008).

Progenitor Species

Unlike other livestock, the domestic goat's progenitor is fairly clear. The Bezoar goat (Capra aegagrus aegagrus) of the Caucasus mountain range, which runs from Southern Russia to Northern Iran, shares the same number of chromosomes as its domestic descendants, as well as a similar horn core shape (Larson, 2011; Zeder, 2001; Zeder, 2006b). Another wild goat, the ibex (Capra ibex), which can breed and produce fertile offspring with domestic goats, has instead a flat anterior keel on its horn cores. Domestic goats and Bezoars have a sharply developed keel, very different from the ibex (Zeder, 2006b). A possible pre-domestication management relationship with imported *Capra aegagrus* on the island of Cyprus has been postulated and seems to have occurred as early as the eleventh millennium (Vigne *et al.*, 2011).

Relevance of Breed Selection

The C haplotype in Europe is confined to a few goats from Slovenia and the Swiss Toggenburg breed of sheep, indicating that they are possibly a remnant population in today's A haplotype dominant populations (Fernandez et. al 2006). This is interesting, as the Swiss Toggenburg is also widely regarded in non-academic discourse to be the oldest breed of dairy goat. Based on the commonness of the C haplotype in the wild Bezoar population, and the breed antiquity of the Toggenburg (as well as the difficulty in obtaining a Bezoar skin) this breed has been chosen as the goat sample for this project.

Feasibility of Sourcing Skin

The Swiss Toggenburg is a rare breed but is raised by a number of breeders in the UK. There is also a British Toggenburg which has a shorter coat that the Swiss breed. Though sourcing this breed proved challenging, a skin was eventually acquired from a breeder who culled young male goats from his herd each fall.

Cattle (*Bos taurus*)

Domestication and Prevalence in the Archaeological Record

The initial domestication of cattle occurred at approximately 10,000 BP in two locations: the Near East and the Indus valley (in modern day Pakistan (Götherström et al., 2005). Two distinctive types of cattle evolved from these two regions, *Bos taurus* from which all European cattle are descended and the humped *Bos indicus* or Zebu from which Indian and North African cattle are descended (Beja-Pereira *et al.*, 2003; Loftus *et al.*, 1994). From this Near Eastern origin, domestic cattle spread west and north into Europe, reaching Greece by ca. 6000 BC, Southern France, Spain and Portugal ca. 5,400 BC, and the northwest coast of Europe between 4000-3000 BC (Bollongino *et al.*, 2006; Bradley and Magee, 2006b). The faunal remains of domestic cattle in the UK extend back to the early Neolithic at sites such as Windmill Hill, and Eton Rowing Lake, and are consistently present throughout the following eras (Armitage, 1982; Viner *et al.*, 2010; Copley *et al.*, 2003).

The presence of domestic cattle in the faunal record, pertinent to the time periods of this project, is well documented (Copley *et al.*, 2003; Armitage, 1982; Beja-Pereira *et al.*, 2003; Bollongino *et al.*, 2006; Europa, 1992; Götherström *et al.*, 2005; Legge, 2010; Rowley-Conwy, 1995c; Ryder, 1980). What is more important for this research is to understand what early cattle may have looked like, therefore better informing the choice of breed for the sample collection. As the Aurochs disappear from the archaeological record in the Bronze Age (Legge, 2010), they have gradually been replaced by domestic cattle, which display important characteristics such as a smaller bone structure, which helps to identify them as domestic (Sherratt, 1983; Moore *et al.*, 2000; Rowley-Conwy, 1995c). Unfortunately, their faunal remains tell us little about the nature of their hide or coat.

For this information, direct evidence is of more use. One item which often survives, even if the dermal material has decayed, is hair. Hair tying modern cattle breeds to their more Aurochs-like ancestors has been studied on a few rare finds, from sites with unusually good preservation. Whereas sheep were selectively bred to produce finer wool over time, cattle have instead become more coarsely haired since domestication. Hair samples from primitive cattle at Skara Brae in Orkney which date to approximately 4000 BP have a mean diameter of 15 µm and samples from the 4000-year-old Meare bow have a mean of 33 µm. Most modern breeds have a mean diameter from 41 to 56 µm, much thicker than their Neolithic ancestors (Ryder, 1980: 390-91).

Evidence of not only hair, but dermal material as well, can be found in the form of processed skin artefacts, found in various preservation contexts. Ötzi had with him clothes and equipment made from calf skin (Egg *et al.*, 2009; Park, 2008; Püntener and Moss, 2010), skin items from both Norwegian glacial sites and the southern Alps have been identified as probable cattle hide (Hafner, 2012; Kamper, 2015; Park, 2008; Schlumbaum *et al.*, 2010; Spangenberg *et al.*, 2010). One of the oldest shoes found in Europe is a specimen found in a dry cave site in Armenia dates to 3627-3377 cal. BC, which in this area places the find in the Chalcolithic and has been preliminarily identified as cow skin. However, this author notes that, at 2.12mm in thickness, it falls below the mean thickness of 4-6 mm for average adult cowskin (Pinhasi *et al.*, 2010).

Genetic Research

Other evidence which weighs into not only understanding the beginnings of domestication, but also the spread of cattle across Europe, and the relationship of today's breeds to early cattle types, is DNA analysis. Evidence for two separate domestication locales for the *taurus* and *idicus* subspecies can be found in their respective Y haplotype signatures. Zebu are predominantly Y3, whereas nearly all European cattle are either Y1 or Y2. The divergence of Y3 and Y2 into separate clades (a group consisting of a species (extant or extinct) and all of its descendants) is calculated to predate domestication by a few thousand years, approximately 13,900 BP (Bollongino *et al.*, 2006; Bradley and Magee, 2006b; Götherström *et al.*, 2005; Loftus *et al.*, 1994).

None of today's Anatolian cattle breeds possess the Y1 haplotype. This haplotype is thought to be a legacy of domestic cows breeding with wild European Aurochs after the introduction of cattle into continental Europe. This scenario seems probable, given that herds were likely free ranging for much of the year (Götherström *et al.*, 2005). Many breeds which are considered primitive breeds are of the Y2 haplotype including the Italian Chianina, Scottish Highland and Galloway cattle (Armitage, 1982; Europa, 1992; Götherström *et al.*, 2005).

MtDNA evidence for European cattle also shows a complex pattern of introduction from the Near East, followed by influxes of maternal DNA from local wild Aurochs in the Mediterranean area and North African stock via maritime routes. The MtDNA haplotypes T, T1, T2 and T3 are all present in Near Eastern cattle. T1 and T3 are respectively the most common North African and European clades, whereas T2 is found almost exclusively in the Near East. T1 does occur around the Mediterranean, including in 16 samples of Bronze Age cattle remains from Spain. Samples of European Aurochs from Southern Italy dated between 7000 and 17,000 years ago showed, interestingly, that modern cattle breeds in Southern Europe are genetically a better match with wild Aurochs from the same area than to Aurochs samples from the Near East. In Northern Europe it would appear that different herd guarding strategies were employed, as no modern breeds share any MtDNA similarity with wild Aurochs samples from the UK. Nearly all cattle in Northern Europe are T3, with the exception of Britain, where a small percentage retain the haplotype of their Near Eastern predecessors (Beja-Pereira *et al.*, 2003; Bollongino *et al.*, 2006; Götherström *et al.*, 2005).

Relevance of Breed Selection

In an effort to choose a breed of cattle that closely resembles the cattle present in the Neolithic and Bronze ages, Y and MtDNA evidence, hair analysis and breed records have been taken into account. Based on these criteria, the Scottish Galloway has been chosen for this project's cattle sample. The Galloway falls into the Y2 haplotype of great antiquity, has a mean hair shaft diameter of 30µm (putting it within the finer range of early cattle and wild Aurochs samples), and has a long shaggy double coat similar to other modern day wild Bovids, like North American Bison (*Bison bison*); these attributes, plus written descriptions of the breed going back to the 1500s, all lend support to this choice (Beja-Pereira *et al.*, 2003; Europa, 1992; Götherström *et al.*, 2005; Legge, 2010; Ryder, 1980; Department of Animal Science, 2008).

Feasibility of Sourcing Skin

The Galloway breed of cattle comes in a number of varieties including Scottish and Belted. Acquiring a hide was feasible as a herd of Belted Galloway was located nearby. The breeder informed the author of the next round of slaughtering, and the skin was procured from the local hide processing plant.

Horse (*Equus caballus*)

Domestication and Prevalence in the Archaeological Record

The horse has shared human history since the Palaeolithic, as evidenced by 30,000-year-old cave paintings in France. Pleistocene horses and their North America counterparts were hunted for food, and the images most likely represent a prey animal as opposed to domesticated livestock. Toward the end of the last ice age (11,000 BP) horses became extinct in North America, and extinct or very rare in many areas of Europe (Anthony, 2009; Bendrey *et al.*, 2010; Olsen, 2006). Two subspecies to escape these extinctions and the only two to survive into historic times were the Tarpan (*Equus ferus ferus*) and the Przewalski's horse (*Equus ferus przewalski*). The Tarpan became extinct in 1919 when the last surviving individual died in a Russian zoo (Olsen, 2006: 246). The Przewalski's horse died out in the wild in the 1960s but was bred in captivity and reintroduced to the wild in the Hustai National Park from 1992-2000, where a breeding population of 150 individuals now lives (Foundation for the Preservation and Protection of the Przewalski Horse 26/02/2011). After the last glaciation (11,400 years ago) (Jansen *et al.*, 2002), with the exception of the Eastern European Steppe and Iberia, horses were not seen in quantity in the archaeological record in Europe, until the Late Neolithic or Early Bronze Age, when they were reintroduced around the time of the Beaker culture circa 4000 BP (Bendrey, 2012; Bendrey *et al.*, 2010; Clutton-Brock, 1999).

The oldest undisputed evidence for horse domestication is approximately 2000 BC in the Middle Bronze Age, based on chariot burials at Krinvoe Ozero in the southern Urals, which are attributed to the Sintashta-Petrovaka culture, which also gave direct evidence for the use of rope or leather bits (Jansen *et al.*, 2002; Olsen, 2006; Anthony, 2009: 402, International Museum of the Horse, 25/02/2011). Earlier evidence for domestication may exist on the Eurasian steppe of Kazakhstan. Dental pathology indicative of bit usage, the presence of traces of fat attributed to equine milk on local pottery, and archaeozoological metrical analysis of horse metapodia (comparing the slenderness of Eneolithic samples from the Botai Culture with samples of relevant known domestic and wild horse metapodia) build a convincing case for horse domestication by 3500 BCE (Anthony, 2009; Outram *et al.*, 2009). Though we now know this was herding of Przewalksi type horses (Gaunitz *et al.*, 2018.)

As with the other domesticates, faunal remains of horses are well documented after their introduction – in this case from 4000 BP onwards across most of Europe, as are perforated antler tines (interpreted as bridle pieces (Olsen, 2006; Anthony, 2009: 242). There are few processed skin finds attributed to horse**.** There is an ethnographic mention of mare skin being used as the face cover for the traditional Yakut girls' wedding outfit in Siberia (Petrova, 2010).

Genetic Research

Genetic research has been has seen more focus on the origins and very early spread of domestic horses than on breed specific analysis. However, some of this can be used to infer which breeds are more closely related to their prehistoric ancestors. The Przewalski horse is the only remaining, and never domesticated, wild horse; all other groups labelled as such are feral, meaning descended from domesticated animals. Genetic studies, however, indicate that our modern breeds do not originate from the Przewalski horse, a species which exhibits three mtDNA haplotypes not found in any breed of modern horse. Instead, the Tarpan subspecies is thought to be the progenitor of our modern horse breeds (Anthony, 2009; Olsen, 2006; Jansen *et al.*, 2002). However, according to Jansen (2002), in order to account for the great diversity and geographic clustering of mtDNA types in modern horses, it is unlikely that they were domesticated from only one group. A more likely scenario involves groups of people migrating with their domesticated horses and capturing local wild mares from differing geographic locations, thereby increasing the genetic diversity of the original herds (Olsen, 2006; Outram *et al.*, 2009). Another option sees domestication knowledge being transferred to neighbouring groups who domesticated animals from locally sourced herds, thereby adding large amounts of genetic diversity to today's breeds. It is also quite possible that horse domestication was simply independently developed by different ancient communities, over a geographically diverse area (Warmuth *et al.*, 2012).

Relevance of Breed Selection

One cluster of mtDNA relevant to this project "is geographically restricted to central Europe, the British Isles, and Scandinavia, including Iceland. A total of 17 of 19 documented horses with C1 (haplotype) are northern European ponies (Exmoor, Fjord, Icelandic, and Scottish Highland)." "The cluster is younger than perhaps 8,000 y, but definitely older than 1,500 y, because C1 was also found in two ancient Viking horses. Furthermore, mtDNA cluster E (*n* _ 16) consists entirely of Icelandic, Shetland, and Fjord ponies. Taken together, this suggests a common late glacial or postglacial origin for these pony breeds (Jansen, *et. al.*, 2002, p.10,908)." Supporting this statement, a second study of mtDNA from 16 samples of frozen Iron Age Scythian horses places one sample into the C1 cluster, which is characteristic of Northern European ponies (Keyser-Tracqui *et al.*, 2005).

Feasibility of Sourcing Skin

The Exmoor pony has been chosen as the horse sample for this project, based on genetic evidence for their genetic similarity to some early horse breeds (Jansen *et al.*, 2002; Keyser-Tracqui *et al.*, 2005; Vilà *et al.*, 2001), its small stature, local availability, and historical records of Exmoor pony broodmares dating back to 1085 (Equine World UK, 26/02/2011). Though challenging to acquire a skin from an animal which is often considered a pet, this variety is kept in many areas of the UK and a skin was sourced from a Scottish breeder when a foal unexpectedly died.

3.4 Introduction to North American Species Selection

North America's vast land mass, diverse terrain and extensive climatic variation make the selection of representative species for the whole continent challenging. To adequately encompass this variety, key factors such as the frequency of a species in the archaeological record through time, their spatial distribution both prehistorically and historically, ethnographic accounts of species targeted in the past, and the feasibility of acquiring a skin, were considered for each of the large game species available in North America. A bias toward large game species is acknowledged, and due in part to the material type which is the focus of this research. In terms of processed skin items, it is likely that a preference would have been shown for skins from larger animals, for hide working purposes. The time needed to tan one deer skin is less than is needed to produce an equal amount of processed skin, in square footage, from a given number of smaller animals. The underrepresentation of small game in the sample collection is, secondarily, due to availability stemming from modern hunting and trapping laws, as well as culinary preference. In many areas rodents such as ground hogs (*Marmota monax*), pack rats (*Neotoma sp.*), marmots (*Marmota flaviventris*) and squirrels (*Sciurus sp.*) would have made up a significant portion of not only the daily caloric intake, but also small processed skin items. These animals are now hunted rarely, as they are seldom eaten. This modern perception of food species is also reflected in the faunal literature, which is often a history of big game use, as opposed to faunal use, as a whole. Due to this bias, and the lack of most small game species in the sample collection, the following discussion will focus more heavily on big game species.

In keeping with the rationale expressed in the thesis introduction, the lower end of the time frame bracketing this project is not firmly set, as glacial and permafrost preservation have proved that processed skin artefacts can and do survive from very early contexts. The upper end of the time frame is also loosely applied, and is, for North America defined as 'prior to contact'. As this varies considerably by location across the North American continent, so too does the upper time bracket for this research. The geographic boundaries for this research, from east to west, encompass the landmass between the Pacific and Atlantic coastlines. They extend as far north as do native groups, and into the arid northern parts of present-day Mexico. The termination at this arid boundary is based in part on preservation potential, as the moist tropical regions further to the south have a smaller chance of preserving processed skin artefacts. Secondly, ethnographically, skin garments are not often worn in these regions as there is less need of thermally protective clothing, and because, from a purely practical standpoint, tannage type aside, skin garments do not cope well with warm, wet environments.

Key Species Use Through Time and General Temporal Trends

Human occupation in North America does not have the same time depth as seen in other parts of the world. However, groups were hunting, camping and creating advanced sets of stone tools by at least 13,500 BP, which were the earliest, until recently, generally accepted radiocarbon dates (Goebel *et al.*, 2008). However, a growing body of convincing evidence for much greater antiquity than this exists (Stanford and Bradley, 2012). The Cactus Hill site in Virginia boasts radiocarbon dates going back to 16,670 BP (Wagner, 2017) and the

Coopers Ferry site in Idaho with numerous radiocarbon dates falling between 14-16,500 BP (Davis *et al*, 2019) are just a few examples of sites with dates supporting these ealier occupations. Other pre-Clovis sites include the Page-Ladson site, Florida; Paisley Caves, Oregon; Schaefer and Hebior, Wisconsin; Meadow Croft, Pennsylvania; Miles Point, Maryland; Parson's Island, Maryland; Topper site, North Carolina, and the Debra L. Fr site, Texas among others (Adavasio *et al.*, 1999; Halligan *et al.*, 2016; Goebel *et al.*, 2008; Stanford and Bradley, 2012; Willams *et al.*, 2019).

The climatic conditions in North America from these early dates into the contact period has not been static. In response to this variability the biodiversity of the various regions has changed through time to cope with warmer and drier, interspersed with cooler and wetter periods. The change in the prey base that results from these fluctuations is also reflected in the procurement strategies of the regions inhabitants (Broughton *et al.*, 2008; Byers and Broughton, 2004; Lyman and Wolverton, 2002; Stahl, 1996). While these adaptations to the changing conditions tend to be regionally specific, the details of which are outside the scope of this research, there are some general trends worth noting. These trends in overall faunal use and climate change have the potential to affect not only what species were available, but possibly what tanning technologies, or sub-methods, were best suited to the changing climatic conditions.

The paleobiological record shows that during the Pleistocene, a cool stable environment characterised by low climatic variability existed, and that this environment supported relatively high plant and animal biodiversity (Stahl, 1996). The density of large game animals available during this period fostered the Clovis culture that is widely believed to have made good use of the abundant megafauna as a large part of its food procurement strategy (Fagan, 1991: 81). However, at approximately 11,000 BP a gradual change to warmer and drier conditions, characterised by more extreme seasonal variation in both temperature and moisture begins (Byers and Broughton, 2004). A complex set of factors including oscillating climatic conditions, led to the extinction of the megafauna which had dominated the last ice age. In response to these new circumstances, later Paleo-Indian groups broadened their subsistence strategies considerably (Byers and Broughton, 2004; Byers *et al.*, 2005; Hill Jr, 2008).

Early Holocene

Groups attempting to adjust to the changing environment to the early Holocene, between 10,000 to 8000 BP, may have faced temperature and moisture shifts more extreme than anytime there after (Byers and Broughton, 2004). These shifts saw the large basin lakes of the west shrink, woodlands diminish, coastal plains flood and of course the glaciers recede. The majority of this change was confined to the early Holocene, with the environment reaching approximately modern conditions in the first part of the Middle Holocene between 8000 and 7000 BP (Fagan, 1991: 92).

The population of North America is believed to have been relatively sparse during this early occupation period, and, though most maintained a focus on big game, the shift toward broader range subsistence strategies had begun in many places (Fagan, 1991: 81). In the Eastern Woodlands the warming temperatures allowed the vast hardwood forests which characterise this region to move steadily northward, as the boreal forests retreated with the Laurentide ice sheet. This steady change of vegetation type was mirrored by the resident species, with cold adapted species moving northward and species such as white tailed (*Odocoileus virginianus*) and mule deer (*Odocoileus hemionus*), whose ability to cope with deep snow is poor, expanding their range (Nowak, 1991: 1285).

Middle Holocene

The Middle Holocene (8000-5000 BP) is often referred to for western North America as the Altithermal and the Hypsithermal for the east (Beaudoin *et al.*, 1996). While the regional weather patterns seen today of summer-dry, winter-wet for areas such as California and the Pacific Northwest and summer-wet, winter-dry for areas such as the Great Basin, Rocky Mountains and Great Plains, were well established by this period, they are believed to have been a more severe version of the average experienced today (Broughton *et al.*, 2008).

The aridity during this period saw artiodactyl numbers drop in many areas of the west, a shift which would inevitably impact the faunal use patterns of these areas. Most saw a shift toward more varied procurement strategies and the use of small game such as rabbits and rodents increased (Broughton *et al.*, 2008; Byers and Broughton, 2004; Byers *et al.*, 2005; Codding *et al.*, 2010).

In the Woodlands the rising temperatures saw the prairie corridor reach its most easterly limit and more savannah type forests proliferated (Fagan, 1991: 99). This parkland biome contains a large diversity of resources which fostered a wide range of adaptive strategies and the population of these regions grew substantially during this time (Nicholson, 1988).

Late Holocene

The dry, arid pattern shifted in the Late Holocene (4500-latest prehistoric) with the overall temperature dropping and cooler moister summers in evidence for the summer-wet areas (Broughton *et al.*, 2008). The Late Holocene (also called the Medithermal) was a stable climatic period overall but, was punctuated by at least three episodes of colder average temperatures (Fagan, 1991: 97). These 'little ice ages' are part of (until recently) a general cooling trend seen over the last 4000-5000 years (Stahl, 1996).

This more stable and generally moister climate saw an increase in the numbers of bison on the Great Plains, and Artiodactyls in the Southwest and Great Basin regions (Broughton *et al.*, 2008; Byers and Broughton, 2004; Byers *et al.*, 2005; Codding *et al.*, 2010). In the east this period is characterised by societies gradually adopting more sedentary lifestyles, with a more pronounced reliance on plants foods and the domestication of a number of native plants as well as introduced Meso-American cultigens (Price, 1985). However, the heavy reliance on deer in the eastern forests as an important source of protein and skins continued unabated (Price, 1985; Gramly, 1977).

Geographic Trends in Faunal Use: Regional vs Continental Significance

Due to the large landmass of North America faunal utilization is typically discussed on a regional basis. These regions fall roughly into a number of environmental types each of which offer regional variation in primary faunal resources. The arctic, the northern boreal forests, the Eastern Woodlands (with the south eastern section often given special mention), the Great Plains (often further split into the northern and southern plains), and the West, with is further subdivided into the Rocky Mountains, the desert Southwest, the Great Basin, and the Pacific Coast (with the Northwest coast as an area of special note). While there are a number of species many of which will be addressed in the furbearer section in more detail, which are found in sites across the continent, for most of the regions listed the primary faunal resources vary.

The arctic areas are characterised by a heavy reliance on faunal resources, of both terrestrial and marine origin, notably seal (*Pinnipedia sp.*) and caribou (*Rangifer tarandus*). There exists a long and intricate tradition of skin processing and garment construction for these areas which have survived into the present day. For a detailed account of the faunal use and skin working traditions of these areas please see (Charles, 2005; Friesen, 2004; Friesen, 2013; Pitul'ko and Kasparov, 1996; Reed, 2005; Oakes and Riewe, 1995; Issenman, 2011; King, 2005).

The boreal spruce and pine forests are low in high calorie vegetable foods (Fagan, 1991: 95). As such they are again a region where game plays an important role, with moose, woodland caribou, small game, and furbearers all being utilized, both as a food resource and a source of skin for the construction of garments and utilitarian items (Helm, 1993; Jarvenpa and Brumbach, 1983a; Young *et al.*, 1991; Holmes, 2001; Irimoto, 1981; Moss and Bowers, 2007; Pitul'ko, 1999; Pitul'ko and Kasparov, 1996; Yesner, 1989).

East of the Great Plains, the heavily wooded areas that make up the Eastern Woodlands were populated by general gatherers for much of the Early and Middle Archaic, with substantial local variation on what was being gathered (Price, 1985). Based on the osteological record the faunal utilization over much of this area is defined by white tail deer hunting and some faunal assemblages are composed of 90 percent white tail deer remains (Fagan, 1991: 325). Secondary use is made of a range of small game such as rabbit and hares (*Leproidae sp*), squirrel (*Sciurus sp.*), turkey (*Meleagris sp.*), racoon (*Procyon lotor*), opossum (*Didelphis virginiana*), and occasionally, not so small game such as black bear (*Ursus americanus*) (Guiry and Grimes, 2013; Jackson and Scott, 2001; Madrigal and Holt, 2002; Price, 1985; Quinn *et al.*, 2008; Carder *et al.*, 2004). In river valleys a more pronounced reliance on aquatic sources of protein such as mussels, fish and crawdads has been noted (Jackson and Scott, 2001; Quinn *et al.*, 2008). Though the importance of skins is not as pronounced as it is in arctic climates, these products are still an important resource in the seasonal environment of eastern North America. In the later Archaic the importance of deer skins as a limited resource, independent of meat yields, has been suggested for possible social conflict, or at least negotiations around resource allocation between native groups (Gramly, 1977; Turner and Santley, 1979; Webster, 1979).

The Great Plains area of North America is unambiguously linked to bison as the primary prey animal, with secondary use of other large game including deer, elk, and pronghorn in the more western portions of the plains (Driver and Maxwell, 2013; Shay, 1978; Driver, 1985; Frison, 2004; Hill Jr, 2008). The harvesting of these secondary animals may be motivated by more than just a desire for culinary variety. Adult bison skin, whilst well suited to making shoes, shelters and robes, is too thick for general clothing construction (Kamper, 2016). Skins from deer, pronghorn and elk offer more suitable material, and may have influenced the frequency with which these species were pursued. Other smaller species of plains dwellers such as badger (*Taxidea taxus*), fox (*Vulpes sp*), skunk (*Mephitidae sp*), beaver (*Castor canadensis*), coyote (*Canis latrans*) and bobcat (*Lynx rufus*) which could provide warm furs and aesthetic variation are frequently seen in the faunal record (Hill Jr, 2008; Hamilton and Nicholson, 2006; Molloy, 1993).

Faunal use in the West as with the rest of the country varies by region, however, there is common reliance through much of the West, on a key set of big game species which include bison, deer (white tail and mule deer), elk, pronghorn, and big horn sheep (Frison, 2004; 1971, Judson *et al.*, 2005; Hill Jr, 2008; LaBelle and Pelton, 2013; Lee, 2012; Brink, 2013; Davis *et al.*, 2000; Hockett *et al.*, 2013; Muir and Driver, 2002; R. Lee, 2005; Tanner, 2000). As mentioned in the general faunal use section, elk for this research designates *Cervus canadensis* as opposed to *Alces alces*, which is labelled as moose.

Elk also goes by the name of wapiti, however this is a niche nomenclature and this species is called elk in the majority of North America. This set of large prey species was supplemented with small game which in some areas, notably the Great Basin, and elsewhere at given points in time, make up a larger percentage of the faunal record than do the larger species (Byers and Broughton, 2004; Thomas, 1969). This area of seasonal temperature extremes requires thermal protection during the winter months, and in the absence of skins from large artiodactyls, inhabitants of this region produced warm, ingeniously constructed robes of rabbit fur wrapped cordage which were then twined together into a single large blanket (Teague and Teiwes, 1998; Wheat, 1967).

In the dry interior of the West bison becomes scarce to non-existent in much of the faunal record, and pronghorn and big horn sheep become the primary big game prey species with large scale trapping complexes constructed as one means of procurement (Bar-Oz and Nadel, 2013; Frison, 1971; Hockett *et al.*, 2013; Bonnichsen *et al.*, 2001; McGuire and Hatoff, 1991). In the desert Southwest much of the diet of later occupation periods was provided by cultivated plants, however, animals were still sought after as an addition to the diet and for the other resources, such as the skins, they provided (Muir and Driver, 2002).

The pacific coastal areas west of the Sierra Nevada Mountains are wetter than the western interior, and supported a healthy population of deer, which form the primary prey species for much of this region, followed by rabbits and later in time a small percentage of elk (Codding *et al.*, 2010). In the Pacific Northwest while deer were still the primary big game species, elk, and pronghorn were frequently utilized and, after 4000 BP, in the eastern parts of the Northwest bison made up a significant proportion of the faunal record (R. Lee, 2005; Lyman and Wolverton, 2002).

As this brief overview highlights, certain animals such as deer and many of the small game and furbearing species were utilized on a continent-wide basis, while others, such as pronghorn and bison were more regionally distributed. Those with a wide distribution such as deer were included in the sample collection based on the high probability that, a large percentage of the processed skin items in prehistory, would have originated from these species. Others, such as big horn sheep, were included due to their intensive localized use, in an effort to make a sample collection containing species relevant to regional, as well as continent wide use.

Overview of Archaeological Evidence

A variety of direct and indirect forms of archaeological evidence from secure temporal contexts exist for North America and provides information about past biodiversity and human utilization of it.

Faunal Presence in Sites

As this field of knowledge is substantial, and ranges over an equally substantial geographic area, the details of the faunal record will be discussed on a species by species basis, within the section devoted to each chosen species. The information reviewed to support the choice of species, came from sites which range in age from 10,000 + BP Paleoindian sites to sites formed in the middle of the 19th century, and covered many of the sub environments comprising the North American continent.

Wild game was taken using a variety of methods, each of which leave a unique signature in the archaeological record. When evidence of procurement methods believed to have been targeted at a specific species such as; trapping, hunting for individual animals (single capture), and mass capture techniques such as drives and corrals, and scavenging, was available it was included in the individual species sections.

Due to the ubiquitous presence of some species in the faunal record, notably deer, their inclusion in the sample collection needed little further justification. However, other species, notably big horn sheep, are found over a much smaller geographical area and as such, a stronger case has been made for their inclusion based on the species regional significance.

In keeping with the rational for the wild species chosen for Europe, genetic studies into variation over the last 10,000 years have not been included for each species, as, based on skeletal comparisons, most have changed little over this time period (Anderson, 1984; Lowe and Gardiner, 1989; Polziehn and Strobeck, 1998; Jong *et al.*, 1995; Meagher, 1986; Lubinski, 2000).

Processed Skin Finds and Ethnographic Evidence of Use

Where presence in the faunal collection lends support for the idea that the skins from species hunted for food would also be used for clothing and utilitarian items, actual skin finds offer concrete evidence of a species utilization in this respect. Though these finds are rare, an effort was made to include any species identified from a archaeologically recovered processed skin object. This could have been a rather extensive list, as a respectable amount of processed skin items exist from various areas in North America. However, a large percentage of archaeologically recovered skin finds are not identified to species due to preservation issues, or a lack of necessary information from which to do so. As in Europe, these skin finds come from a variety of preservation contexts including frozen, wet and dry sites (Beattie *et al.*, 2000; Park, 2008; Kuttruff *et al.*, 1998; King and Gardner, 1981; Sievert, 2011; Taylor, 1988). Thanks to the aridity of the western half of North America there exists a rather extensive collection of skin artefacts from this area covering a significant time span.

While some of these items have well established contexts, many acquired by early collectors, have little information accompanying them, other than the general areas from which they were taken.

In addition to extant processed skin finds, in the event that there is an established ethnographic preference for a particular species, such as the stated preference in the American Southwest towards desert bighorn sheep skins for clothing. Then a skin from that species has been secured when possible, in an effort to provide a sample which may help to identify any similar species preferences in the past.

Rock Art and Associated Artefacts

Large panels of rock art exist in many parts of North America, which document not only single animals but entire hunting scenes (Gilreath and Hildebrandt, 2008; Sundstrom, 1989; Garfinkel *et al.*, 2010; Matheny *et al.*, 1997; Schaafsma, 1986; Wilke, 2013). Though some of the animals depicted show a certain amount of artistic license, a large majority are identifiable to species, gender and sometimes age. These represent an important window into past activities and events, which were important enough to the people who engaged in them to merit recording them in a permanent, and labour-intensive fashion.

Each of the following species has been assessed based on the criteria discussed above and found to be a key species of importance either on a regional or continental scale. The selection of species presented here by no means represents an exhaustive list of the species being used over the North American continent. It does, however, include a significant portion of the species known to have been heavily relied upon over the course of North American prehistory.

Unless otherwise noted, all skins were kindly provided by the Wyoming State Game and Fish department.

3.5 Selected North American Species

Mule and White Tail Deer (Odocoileus hemionus & virginianus)

Name:	Mule Deer (*Odocoileus hemionus*)	
Also known as:	California mule deer, black-tailed deer	
Physical Characteristics:	Sexual Dimorphism: Males are usually heavier than females.	
	Males	**Females**
Length:	1.3-1.7 m (4.3-5.6 ft)	1.3-1.6 m (4.3-5.24 ft)
Weight:	40-120 kg (88-265 lbs)	30-80 kg (66-176 lbs)
Pelage:	Lighter underbellies with darker back, sides and legs. Coats are greyer in winter, reddish brown during the summer. Tail is white or black above and tipped with black. (http://www.mnh.si.edu/mna/main.cfm)	

Name:	White Tail Deer (*Odocoileus virginianus)*	
Also known as:		
Physical Characteristics:	Sexual Dimorphism: Males are about 20% larger than females.	
	Males	**Females**
Length:	0.85-2.4 m (2.8-7.8 ft)	
Weight:	22-137 kg (48.5-302 lbs)	
Pelage:	Brownish grey uppers during winter giving way to reddish brown during summer, with lighter bellies all year round. The distinctive tail is long, brown above and bright white underneath. (http://www.mnh.si.edu/mna/main.cfm)	

Mule deer are identifiable at a distance by their distinctive large ears and their unusual running gait. They spring off all four feet simultaneously in a bouncing motion called stotting. White tail deer are easily distinguished from mule deer by their longer tails with bright white undersides, which they carry upright like a flag when alarmed (Macdonald, 2005: 210; Nowak, 1991: 1385). Antlers on mule deer branch in two nearly equal parts, as opposed to white tail antlers, which have tines growing nearly vertically from a main beam (Anderson, 1984; Jacobson, 2003). Fawns of both species have white spots which disappear at three to four months of age.

Prehistoric and Modern Range

Deer are found throughout the United States, into Central America, and as far north as the Canadian tundra. They range from the high alpine areas of the Rocky Mountains to low lying areas of the desert South West. Though mule deer and white tail now share many of the same habitats, historically there was a more distinct east-west divide between the species, with white tail inhabiting the eastern half of the continent and mule deer the west, with the rough divide beginning along the foothills of the western Great Plains (Anderson, 1984; Frison, 2004; Whittaker and Lindzey, 2004). The exact areas of overlap between the two species historically are obscured by a lack of cranial elements in archaeological sites that can be used to differentiate between the two species (Jacobson, 2003).

White tail are very widespread and currently inhabit most of the coterminous United States, estimates state there may be as many as 15 million in North America. Of the two species white tail vary the most in size dependent on latitude and elevation with smaller body sizes being recorded at lower elevations and in more southerly habitats (Nowak, 1991: 1385). They occur further south than mule deer having been observed in northern South America (Anderson, 1984; Whittaker and Lindzey, 2004). White tail territory has expanded considerably with the increase of farming, the small amount of archaeological evidence in the western US may be attributable to this.

Habitat Preference and Behavioural Characteristics

Both mule deer and white tail have excellent binocular eyesight, and most likely see in colour (Anderson, 1984). Unlike elk (wapiti), deer do not congregate in large groups, and a typical social unit is made up of a female, her yearling daughters and the present year's fawns. Though some male fawns continue to follow their mothers into their second year, most leave after one. In some areas, multiple females develop loose bonds and lasting associations. During the winter months, larger herds of all ages and both sexes may gather in desirable forage areas, a habit termed 'yarding' (Nowak, 1991: 1385). The designation of browser for deer is slightly erroneous, as they are highly dependent on succulent forage. Their reliance on woody twigs seen in winter months is not sufficient, without significant amounts of body fat to sustain the animals' metabolism and, due to this annual cycle of forage, they are better classified as intermediate feeders (Anderson, 1984).

Mule deer are at home in a broad range of habitats from forest to brush land and migrate between summer and winter range. Breeding occurs in late November through mid-December, with most births falling between mid-June and early July. Twins are the most common number of young, but single births are frequent and triplets and even quadruplets not unheard of (Anderson, 1984). Mule deer have distinctive spring and fall migrations, most likely in response to snowfall, as depths in excess of 51 to 60 cm (20 to 24 inches) impede foraging. As mule deer inhabit topographically varied terrain, many migrations are from higher elevations to lower, and vice versa in the spring. The same migration routes appear to be followed by individuals year after year – a tendency exploited by prehistoric hunters (Anderson, 1984; Frison, 2004).

White tail deer occupy a wide range of habitats but prefer more cover than mule deer. This preference for different habitats likely accounts for the rarity of hybridisation (Whittaker and Lindzey, 2004; Hornbeck and Mahoney, 2000). The population and distribution of white tail has increased since historic times. Logging has precipitated an ingression into northern boreal zones, and the patchwork of farmland and irrigated pastures has allowed occupation of arid parts of the Southwest (Anderson, 1984; Frison, 2004). In otherwise unsuitable environments, white tail will make use of river bottoms with adequate cover. They are less migratory than mule deer, but in montane environments and areas of high snow fall, short migrations are observed (Anderson, 1984). White tail are crepuscular, intermediate feeders, and show a tendency to freeze instead of run if they are in cover (Nowak, 1991: 1385). They are, however, capable of quick getaways, using a galloping gait if startled. Two types of social groups are observed: family groups with a dominant female and her offspring; and bachelor groups made up of mostly adult males (Anderson, 1984). Because of the variety of habitats inhabited by white tail, the breeding season varies significantly, however, fawns are born approximately 200 days after breeding (Macdonald, 2005: 210). Rubs and scent marking are major parts of the rut for males and signal both males and females that there is a mature buck in the vicinity (Anderson, 1984).

Hunting Strategies

Due to the vast geographical distribution of deer, procurement strategies are numerous. As with other prey species, the most effective strategies take advantage of behaviour peculiarities, such as mule deer's tendency to run a short distance when startled, then stop to look backward, presenting the hunter with one of the better shots when using a bow (Frison, 2004: 171). Mule deer and white tail's responses to predators differ significantly. White tail can and will outrun predators such as coyote (*Canis latrans*), whereas mule deer are slower and prefer to form a tight bunch and confront the attacking canids (Lingle, 2002). When forced to run, mule deer run up slopes, while white tail run down and away from slopes (Lingle, 2002). These tendencies would have been well known to early hunters and would influence where hunters positioned themselves or their traps.

While deer were likely taken individually by ambushing from blinds, stalking, baiting and decoying in ways similar to hunters of today, there is also evidence for mass capture trapping in the form of rock art. In the California, Northern Plateau and Northwest coast areas procurement strategies documented ethnographically include: individual traps such as snares, and pitfalls, as well as communal netting; and drives into enclosures, pits, over cliffs, and onto thin ice using pedestrians, fire and even specially trained dogs to encourage the deer in the direction of choice (Anell, 1969; LaBelle and Pelton, 2013). These areas are outside the range of bison, so more intensive efforts are likely to have been made in deer procurement, as it would have been the largest game animal present (Frison, 2004; 1991). White tail are the smaller of the two subspecies and can provide between 4.5 kg (10 lbs) of meat from a small female fawn to 20 kg (45 lbs) from a yearling buck (Madrigal and Holt, 2002). Mule deer are larger, and a big buck can provide as much as 45 kg (99 lbs) of meat (Frison, 2004: 172). 74,261.4 is the amount kilocalories from both meat and marrow given in Madrigal and Holt's 2002 experiment after processing and assessing the yields from 11 white tail deer. This number of calories would support a single person on a 2000 calorie a day diet for 37.3 days and 29.8 days on 2500 calories a day. This number does not include any edible organs (and presumably organ fat as the deer were field dressed) or calories from the head. This is a recurring difficulty in figuring a per animal caloric return based on modern butchering practices, which do not make intensive use of the entire animal as would often have been done prehistorically. Though not numerous in Paleoindian sites, deer remains are found indicating that they were hunted with atlatls, as well as with bow and arrows (Frison, 2004: 173).

Prevalence in the Archaeological Record

Deer remains are ubiquitous to archaeological sites with good bone preservation in North America (Price, 1985; Madrigal and Holt, 2002; Parmalee, 1962; Frison, 2004; Jacobson, 2003) – so much so that this statement is seldom cited in the literature. White tail deer are arguably the most important game animal in the Eastern Woodlands, and both mule deer and white tail are found in archaeological contexts, even in areas where bison hunting was the main focus of game procurement (Madrigal and Holt, 2002; Shay, 1978; Sundstrom, 1989). A few sites which highlight the importance of deer as a resource include the Pecho Coast of California, where eleven sites with occupations from 9,000-500 BP show deer remains dominating the faunal assemblage in all but two components. Deer were likely a status animal in this area, imparting social benefits, as evidenced by continued pursuit even in times of local scarcity (Codding *et al.*, 2010). The Dead Indian Creek site, occupied from 4,500-4,000 years ago in north western Wyoming, contained the remains of at least fifty individuals, which appear to have been killed during the winter months (Frison, 2004: 174).

The D. C. Corral structure in the Jarbridge Mountains in eastern Nevada is believed to be a procurement structure designed for mule deer. Along with others in western Nevada and eastern California, it is found at higher elevations and in rougher topography than is typically associated with pronghorn trapping. The traps are also located along known modern migration routes for mule deer (Hockett *et al.*, 2013). The Sawtooth Drive site, another high alpine set of drive lines in Colorado, yielded mule deer remains, attesting to its use for at least occasionally procuring this species (LaBelle and Pelton, 2013). Testing of strontium levels from human bone from mortuary complexes in the Midwest showed that, for those tested, plant foods made up only 20% of the local diet. As white tail were by far the most numerous large game animal present in the faunal assemblage, it looks as though this species made up a significant portion of the remaining 80% (Price, 1985). Due to the difficulty in differentiating between mule deer and white tail post-cranial remains, they are often lumped together as *Odocoileus spp.* Jacobson (2003), however, has introduced some useful post-cranial identification characteristics for the two species.

In addition to their continuous presence in the archaeological record, the importance of deer as a game species is illustrated in rock art throughout the western United States. Panels in the Black Hills of South Dakota depict deer being driven into enclosures made of nets, or possibly strung up hides, as depicted by a horizontal line with continuous loops attached to the underside. Both men and women are portrayed in these hunting scenes (Sundstrom, 1989). I have chosen mule deer over white tail based solely on the availability of their hides. The majority of my contacts for acquiring hides live in Wyoming and Colorado, where mule deer are more populous than white tail, and are therefore more easily acquired.

Genetic Research

Hybrids between the two species occur in captivity, and F_1 crosses are sometimes fertile, though direct mating between this generation produce infertile offspring. Wild hybrids have also been documented in Oregon, Texas and Alberta, but are thought to be rare (Anderson, 1984; Hornbeck and Mahoney, 2000).

Feasibility of Sourcing Skin

Easy, large population, extensively hunted, as well as being frequently hit by cars.

Bison (Bison bison)

Name:	Bison (*Bison bison)*	
Also known as:	American Buffalo The European sub-species are called wisent (*Bison bonsus*).	
Physical Characteristics:	Sexual Dimorphism: Males are larger than females. Both sexes have horns.	
	Males	**Females**
Length:	3.1-3.8 m (10.2-12.5 ft)	2.1-3.2 m (6.9-10.5 lbs)
Weight:	460-907 kg (1,014-2,000 lbs)	360-544 kg (794-1,200 lbs)
Pelage:	Dark brown with a thick shaggy mane on males. Calves are a bright reddish brown colour until they begin to darken at two months old. (http://www.mnh.si.edu/mna/main.cfm)	

Bison, perhaps more than any other animal, are an iconic symbol of the pre-contact Great Plains and the Old West. They are the largest terrestrial mammal in North America, and there is a wealth of evidence, both ethnographic and archaeological, which highlights their importance as a critical subsistence item. With the exception of deer, bison are the most widely utilised big game animal in western North America. They are found in faunal assemblages from Alaska to northern Mexico, and from the Great Basin in the west to the Appalachian Mountains in the east (Bozell, 1995; Bamforth, 1987; Creel, 1991; Gilbert, 1969; Meagher, 1986; Shay, 1978).

Prehistoric and Modern Range

Bison (often referred to as buffalo) are the descendants of (*Bison latifrons),* a much larger, longer-horned variety of the Pleistocene (Frison, 2004: 62). Modern bison (*Bison bison*), like their ancestors, are grazers that congregate in large herds. Some of these herds awed the early Euroamericans who first observed them, who described their numbers in the tens of thousands (Bamforth, 1987). The bison's core range is the rolling grass lands, which extend from northern Mexico into southern Canada, and this is where the majority of their numbers were located. However, smaller numbers of bison were recorded as far east as the Appalachian Mountains, and into the Great Basin west of the Rocky Mountains. A subspecies, *B. bison athabascae,* inhabited the boreal forests of Canada and Alaska. The Alaskan population is known from non-fossilised skeletal elements and were extinct in this area by historic times (Shay, 1978).

With the advance of European settlers, bison were hunted to near extinction in the late 19th century by professional hunters killing animals to feed railway builders and hide hunters supplying the demand for pelts. Large numbers were also killed as a way to force the native populations into permanent settlements on Reservations and, in some cases, simply to make room for cattle. They dropped from tens of millions of animals to a mere 541 animals at their most critical point, over little more than a hundred-year period (Bozell, 1995; Jong *et al.*, 1995; Meagher, 1986; Shay, 1978). Today's bison are the descendants of these remnant populations, which survived in inaccessible or protected areas such as Yellowstone National Park. After protected status was given to this species, they were successfully reintroduced to many areas of private land, as well as some state and national parks (Jong *et al.*, 1995).

Bison have been hunted since the late Pleistocene through to historic times. With the exception of a span of time from 8000 years ago to 5000 years ago (Altithermal), which saw the numbers of bison on the plains drastically reduced in number due to very dry conditions, bison have been the dominant grazing species of a large part of western North America (Frison, 2004: 64). The wisent (*Bison bonsus*) a very close relation of the American bison, once inhabited much of Europe. The Romans recorded herds containing thousands of individuals in present day Germany and Belgium. The clearing of land for farming and animal rearing reduced the wisent's traditional range to small parts of Poland and the Caucasus by the late 1800s. The Caucasus herd was extinct by 1925, and the Polish herd was killed in 1919 during the First World War. Wisent have since been reintroduced into a semi-wild state in the Bialowiecza forest in Poland, where the population is now self-sustaining (Nowak, 1991: 1433; Macdonald, 2005: 214).

Habitat Preference and Behavioural Characteristics

Bison originally occupied a diverse number of habitats, from mountain valleys to desert basins, and elevations ranging from sea level to 3,900 meters (Frison, 2004; Meagher, 1986). They are gregarious, and form large, mixed-sex herds mostly composed of cows and their calves, which stay with their mothers for up to two years. Cows will aggressively defend their calves. Males come and go from the main herd, and bulls over seven years old have a tendency toward more solitary behaviour. The main herd is generally led by a dominant cow (Meagher, 1986; Macdonald, 2005).

Bison migrate during the fall and spring and have mini migrations between different prairie food zones during the summer. Early in the summer, they prefer short and mixed grass zones, then move toward the tall grass zones as these late season grasses mature. It is estimated that tall grass prairie can support 3-6 bison per square kilometre (Shay, 1978). In areas such as Yellowstone, groups of bison migrate up in elevation during the summers, and back down into the lower valleys to winter. North American bison are grazers, while European wisent prefer forested areas and will happily browse in addition to grazing. Both species are typically diurnal but are known to move about at any hour (Nowak, 1991: 1433; Macdonald, 2005: 214).

Hunting Strategies

Bison were hunted using both single and communal kill strategies. Communal strategies made use of bison's herd instincts and tendency to follow a lead animal, relying on the animal in front to turn away from any danger, thus signalling the animals behind to do the same. Steep-sided dead-end arroyos, wooden corrals with long wings either side, and even parabolic dunes were used as traps where hunters with spears, or arrows waited to dispatch the cornered animals (Bamforth, 1987; Gilbert, 1969; Shay, 1978; Frison, 2004). There are 53 of these bison drive sites located on what is currently the Blackfoot reservation in Montana alone, a testament to the popularity of this method of capture (Gilbert, 1969). Perhaps the most well know mass-capture technique is the bison jump. This method involves running a large herd over a steep drop, where many are killed outright and others are seriously injured making them easier to kill. In addition to the requisite drop-off, many of these sites also have long wooden or stone drive lines extending back from the drop off to manoeuvre the animals into the proper location (Frison, 2004; Bamforth, 1987).

Just one average-sized bison cow can provide at least 400 pounds (181 kg) of meat, as well as a densely furred pelt for clothing or bedding. This, in addition to a sinew for binding, edible or utilitarian innards, and large amounts of bone for tools, makes the large amount effort expended to construct the components seen at mass kill sites, and the inherent danger in attempting to manipulate a group of large, agile and often aggressive animals, more understandable.

Hunting individual animals was of course also practised and is most likely the more common of the two procurement strategies, but the mass kill sites simply leave a more obvious mark in the archaeological record. Communal hunts may have happened as infrequently as every few years, when all the elements needed for successful implementation were in place. Single animals could of course be taken any time a favourable opportunity presented itself. Single individuals could have been hunted from blinds at watering holes or choke points on migration routes or, if a hunter was very stealthy, picked off from the edges of the herds. This type of single animal procurement was made much more efficient from the 1600s onward, when native groups on the plains acquired horses, and could ride at the same speed as a fleeing bison. (Frison, 2004; Bamforth, 1987; Bozell, 1995)

Prevalence in the Archaeological Record and Ethnographic Support

Evidence for the importance of bison hunting is illustrated by Frison (2004: 66), who shows 43 sites containing bison remains, 34 of which were communal kill sites. These sites cover 9 states and one Canadian province, with Texas at the southern end and Alberta, Canada in the North. Shay's (1978) investigation of 100 sites from the Midwest, from 1500 BC to historic times, also highlights the significance of bison as a resource. He found that bison made up 75% of the identified faunal in sites from mixed grass areas, 50% from tall grass, 6-25% in the northern and southern margins, and 5% or less in the far eastern savannah. Interestingly, he also notes that, during a 500-year interval, from 1400-1900 AD, bison expand their eastern range twelvefold, with sightings by Spanish explorers in the 16th century in the extreme southeast portions of the country (Shay, 1978). In a survey of sites dating from 600 BC to 1600 AD in South Dakota, Gilbert (1969) states that bison were generally the preferred prey species for this area, based on available faunal data, but also noted a few sites where, even though bison were locally available, the groups seemed to be targeting deer and pronghorn instead.

Later in time, there is direct ethnographic support for the importance of bison robes, both as a thermally effective item of dress and as an object for trade. Observations by early Spanish explorer Cabeza de Vaca in the 1520s, and during the later Coranado expedition, note the vast trade networks the Southern Plains groups established with the Pueblos to the west, the Caddoans to the south in present day Texas, and as far east as present day Florida, which dealt heavily in bison robes (Creel, 1991). The De Soto Expedition in 1541 mentions the use of bison robes in the south eastern woodlands of present-day Arkansas (Bourne, 1973: 139-140, in Creel, 1991: 41). In 1691, Fray Casañas mentions the Hasinai tribe of east central Texas using bison robes for bedding, and carefully dressed deer skins for clothes (Joutel, 1966: 109-111, in Creel, 1991: 41), and on page 303 (Kidder, 1932) mentions mounds of soft woolly brown hair found in excavations at Pecos Pueblo, which he interprets as coming from robes that were used to wrap the dead.

Creel (1991) postulates that the importance of bison hide exchange noted by the early Spanish and French visitors to the Southern Plains had been going on since at least as early as 1300 AD. He bases this on the reappearance of end scrapers, and two- and four-edged bevelled knives widely believed to be closely linked to skinning and processing large hides.

Sites containing evidence of bison exploitation cover the entire span of human occupation in North America, with the oldest sites dating to at least 11,000 years ago and continuing as a nearly unbroken tradition through to historic times (Bozell, 1995; Gilbert, 1969; Holmes, 2001; Shay, 1978; Cannon and Meltzer, 2004). This combined with the large amount of ethnographic data on the importance of bison robes and their far-reaching trade, argues strongly for the inclusion of bison in the sample collection for this project.

Genetic Research

As with many of North America's wild animals, bison, based on the faunal record, have changed little since the last ice age. There is little phenotypic variation between the subspecies, and it is felt that what little there is, would not be reflected significantly in the skin morphology.

Feasibility of Sourcing Skin

Moderately difficult, small population, no hunting season, few road kills, but are raised commercially.

Skin kindly provided by Matt Richards of Traditional Tanners (www.braintan.com).

Pronghorn Antelope (Antilocapra americana)

Name:	Pronghorn Antelope (*Antilocapra americana*)	
Also known as:	antelope, pronghorn, verrendo	
Physical Characteristics:	Sexual Dimorphism: Males on average 10% larger than females. Both sexes have horns.	
	Males	**Females**
Length:	1.3-1.5 m (4.3-4.9 ft)	1.3-1.5 m (4.3-4.9 ft)
Weight:	42-59 kg (92.6-130 lbs)	41-50 kg (90.4-110.2 lbs)
Pelage:	Reddish-brown across the upper portions, while the belly, rump and two bands on the neck are white. Both sexes have a black neck marking just below the back of the jaw, and males also have black facial markings (Nowak, 1991; Lubinski, 2000) (http://www.mnh.si.edu/mna/main.cfm).	

Pronghorn are a species native only to North America and are the only extant member of the family *Antilocapridae*. Thirteen other genera of Antilocapridae existed during the Pleistocene but died out as the climate gradually grew warmer and dryer (Nowak, 1991: 1405). Pronghorn are so named because of their distinctive forked horns, which are shed once a year after the mating season concludes. They are unique in this phenomenon, being the only horned North American ungulate to do so (Lubinski, 2000). Both sexes possess horns, though those of females are smaller and do not fork. Pronghorns are adapted to large open spaces, where their excellent eyesight and impressive speed help them avoid predation. They have been observed running at speeds up to 70 miles per hour (113 kilometres per hour) for short bursts, and can maintain slower, but still impressive, speeds for three to four miles (Nowak, 1991: 1405; Frison, 2004: 124).

Prehistoric and Modern Range

Historically, pronghorn ranged from Canada to Mexico, and from the Great Plains to the Pacific coast (Walker, 2000). The advent of fences, commercial meat hunting and competition from domestic livestock caused a sharp decrease in their numbers at the end of the 19th century. It is estimated that 35 million Pronghorn were present prior to European arrival. This number dropped to less than 30,000 by 1924 (Lubinski, 2000). Pronghorn are susceptible to diseases such as scabies and tuberculosis carried by domestic sheep and are less capable of jumping over fences than deer, which has led to interruptions in migratory patterns as well as increased mortality due to entanglement (Nowak, 1991; Frison, 2004; Lubinski, 1999; 2000).

Habitat Preference and Behavioural Characteristics

Pronghorn prefer open plains, rolling hills and shrub lands, where their speed and excellent distance vision (which can identify objects more than a mile away) help them to identify and escape predators (Wilke, 2013; Nowak, 1991). Though their distance vision is well developed, they lack visual acuity and are known to ignore even nearby animals as long as they remain motionless. Pronghorn display a strong sense of curiosity and will often approach a strange object to investigate it more closely (Frison, 2004; Nowak, 1991; Brink, 2013; Tanner, 2000). They are active both nocturnally and diurnally, with slight peaks in activity just after sunset and before sunrise (Nowak, 1991: 1405). They are well adapted to their often dry habitats and are opportunistic feeders who will forage for whatever is most nutritionally advantageous seasonally, opting to browse on shrubs, followed by forbs, with grass low on the preference list (Lubinski, 2000; Walker, 2000). While they will come in for water daily when it is available but are capable of living for long periods of time on the moisture gained from their forage. Male pronghorn have 9 scent glands: 2 over the rump, 4 between the toes, 2 beneath the ears, and 1 above the tail. Females have just 6 and lack those below the ears and above the tail (Nowak, 1991: 1406). Scent from the glands is used to mark territories and during mating displays. Pronghorn migrate seasonally and can move up to 150 miles (241 kilometers) between summer and winter range. Winter herds are the largest and can contain up to 1,000 individuals. In the spring, the groups split into doe and fawn herds and bachelor herds, with old males often becoming solitary (Nowak, 1991; Frison, 2004; Lubinski, 2000). As mentioned earlier, pronghorn dislike jumping vertically, though they can broad jump between fourteen and twenty-seven feet (4.3-8.23 meters). When a fence is encountered, they will walk along it for great distances searching for an opening, or attempt wriggle underneath (Frison, 2004: 124).

Hunting Strategies

Pronghorn have been hunted using numerous methods, from prehistoric times continuously through to the modern day (where approximately 40,000 animals are culled annually (Nowak, 1991; Lubinski, 1999)). They were hunted across their range, in some areas more heavily than either deer or bison, which often shared the same habitats (Gilbert, 1969). This may have been due to the variety of methods which are effective for hunting Pronghorn. As with most species, individuals were hunted by single hunters, who could effectively hide in a blind near a watering hole and wait for the animals coming to drink.

The curiosity displayed by pronghorn can be used to lure them into bow range using bits of ribbon, blankets or decoys – a technique still used by modern bow hunters today (Frison, 2004; Lubinski, 1999). If found in broken ground, stalking is also a viable option, though not often a successful one, unless there is a reasonable amount of cover (Frison, 2004; Lubinski, 2000). Even though Pronghorn are relatively small in comparison to other available big game in their range, an average individual provides approximately 11.5 kg (25 pounds) of meat and another 65 grams (0.143 pounds) of marrow, for a total of about 69,000 kcal (O'Brien and Liebert, 2014). With a given estimate of 2,000 to 2,500 kcal per day needed for an average active human adult, one Pronghorn could provide food for a single person for a month, making it well worth the effort of both single pursuit, and the more labour-intensive communal hunting methods.

Predictable seasonal migrations of large herds, the unwillingness to jump vertically, and the ability to be driven if carefully directed, allow Pronghorn to be hunted not only individually, but also trapped en masse. These large-scale hunts required the cooperation of a group, who first built a circular corral with two wings running out to either side of the corral opening to form a large funnel. The animals were directed between the wings of the funnel by hunters, where their refusal to jump the sides allowed them to be chased into the corral, where they were dispatched (Brink, 2013; Frison, 1971; Lubinski, 1999; Wilke, 2013; Frison, 2004). The lack of large numbers of projectile points expected in or near the corral can be explained by the ethnographically documented use of clubs as the weapon of choice for Pronghorn drives (Frison, 2004; 1971; Lubinski, 1999; Sundstrom, 2000; Tanner, 2000).

Ethnographic and historic accounts can be grouped into three main types of communal procurement strategies: drives, surrounds and chases (Lubinski, 2000; Sundstrom, 2000). These three strategies are echoed in the archaeology of the western Great Plains and the Intermountain zones.

Drives are perhaps the best documented technique in that they have the potential to provide a substantial number of animals and leave the most obvious signature archaeologically. They use long wings, between which the drivers gently encourage the animals. These wings can direct the animals past waiting hunters, into a structure such as a fenced enclosure (corral), into a pit and occasionally over a cliff (Frison, 2004; Lubinski, 2000; 1999; Sundstrom, 2000).

Surrounds involved large groups of hunters encircling a group of animals which were herded into a more concentrated group, which could then be more easily shot or clubbed (Frison, 2004; Lubinski, 2000; Lubinski, 1999; Sundstrom, 2000). Chases, though common for bison on the Great Plains, are rarely mentioned in relation to antelope. When the chases are noted, they are described as a group of mounted hunters chasing down groups of pronghorn, apparently relying on a horse's greater stamina, if not speed, to get them close enough for a killing shot (Frison, 2004; Lubinski, 2000).

Prevalence in the Archaeological Record and Ethnographic Support

There is extensive evidence, both archaeological and ethnographic, pointing to pronghorn's importance as a resource, especially in areas where other large game is scarce, such as the Great Basin between the Sierra Nevada and Rocky Mountain ranges (Brink, 2013; Davis *et al.*, 2000; Frison, 1971 Lubinski, 2000; 1999; O'Brien and Liebert, 2014; Smith, 2013; Sundstrom, 2000; Tanner, 2000; Wilke, 2013).

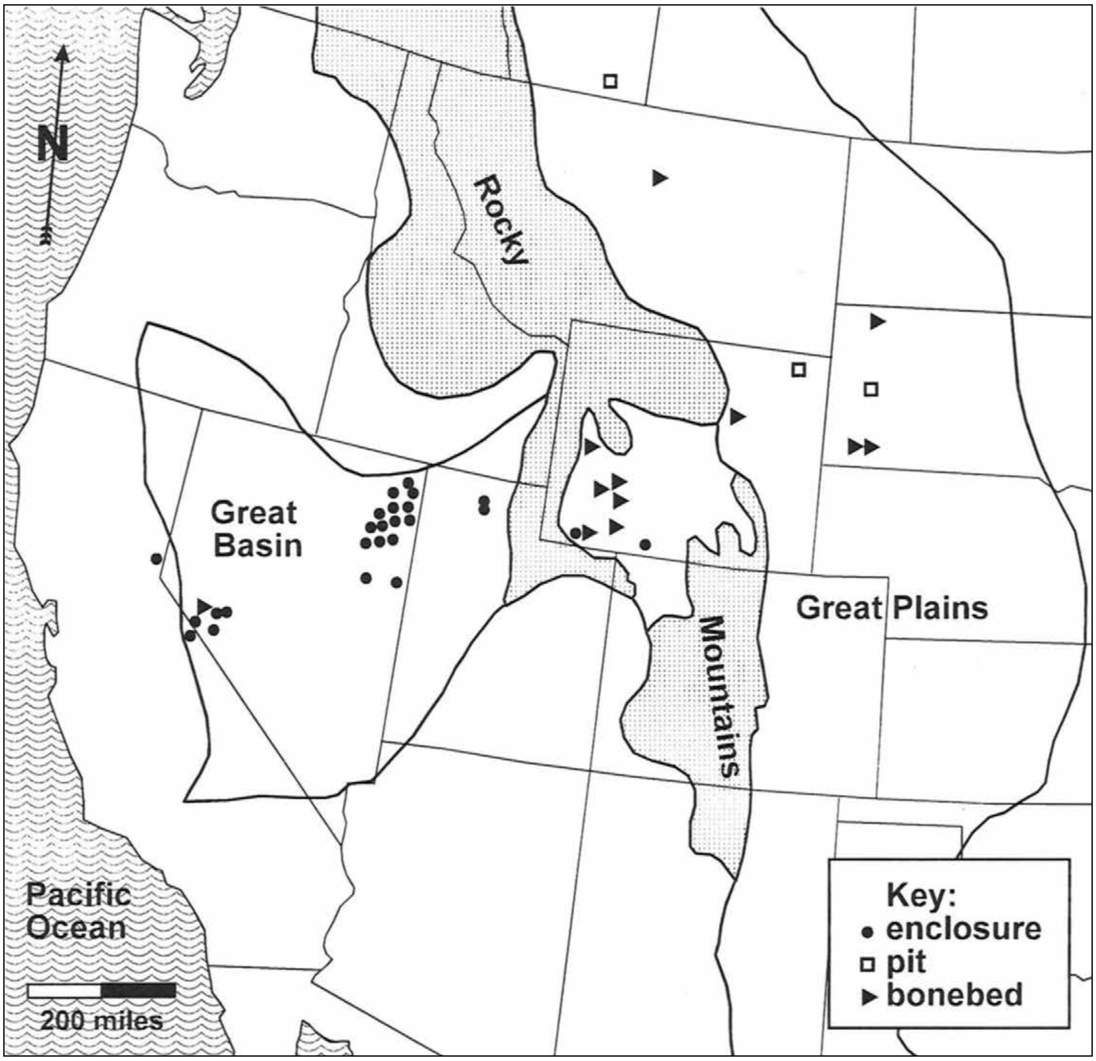


Figure. 3.5-1. Distribution of extant pronghorn traps and bone bed sites in western North America. (Lubinski, 1999: 167).

They were also sought after for their lightweight skins, which were desirable for clothing, being thin and soft yet durable, and of even thickness after processing (Lubinski, 1999; Kamper, 2016; Tanner, 2000; Sundstrom, 2000; Brink, 2013).

Only a few ethnographic reports mention actual numbers of either participants or the number of animals taken during a communal hunt. An entry made by Lewis and Clark on the November the fifth 1804 sheds some light on how successful these communal hunts could be, as they discuss their observations of a Mandan coral drive where 100 animals were taken (Lubinski, 1999; 2000). In another example, a Northern Paiute man recalled 15 to 20 camps converging for a communal hunt, where at least 100 men were present (Lubinski, 1999: 164), making a case for these hunts being important social events as well as providing large amounts of food and resources (Sundstrom, 2000; Tanner, 2000). Using pits at the end of drive lines has not been documented in the Intermountain areas, but only on the Great Plains, where pits 4-6 meters long by 2 meters wide and up to 4 meters deep were dug at the end of drive lines. They were often obscured by covering them with vegetation, to avoid the animals jumping over the pit (which they are capable of clearing with ease (Lubinski, 2000; Sundstrom, 2000)). Another very early report of a successful drive style hunt was made the Spanish explorer Juan de Torquemada in 1542. He records watching a hunt in the Mexican state of Hidalgo where 600 'deer' were taken, including *verrendo* (the Spanish name for Pronghorn (Tanner, 2000).

Less well known, but interesting, evidence of Pronghorn hunting can be seen in artwork from Lakota winter-counts, which records successful communal hunts during 1828-29, 1855-56 and 1860-61. Cheyenne

Site	Location	Mean Age (RCYBP)	Pronghorn MNI	%of site MNI total	Reference
			GREAT BASIN		
Whisky Flat	W NV	none	8	Unk[b]	Yohe 1985
26MN715	W NV	1,750	21	62	Dansie 1990
			ROCKY MOUNTAINS		
Trappers Point	SW WY	5,587	27	54	Miller et al. 1999
Austin Wash	SW WY	1,187	15	60	Schroedl 1985
Firehole Basin	SW WY	628	26	84	Lubinski and Metcalf 1996
Eden Farson	SW WY	230	212	95	Frison 1971
Gailiun	SW WY	150	8	Unk	Current 1993; Lubinski 1997
Boar's Tusk	SW WY	100	6	Unk	Fisher 1981; Lubinski 1997
			GREAT PLAINS		
Lost Terrace	N MT	1,061	41	93	Davis and Fisher 1988
Lighting Spring (Strata 8-14)	NW SD	4,038	8	57	Keyser and Davis 1984; Keyser and Wettstaed 1995
39FA23	SW SD	688	15[c]	52	Lippincott 1996
39FA83	SW SD	none	31	Unk	White 1952
48CA1391 (Component 2)	NE WY	2,760	5	50	McKibbin et al. 1988

Figure. 3.5-2. Pronghorn Bonebed Sites in North America[a] (Lubinski, 2000: 169)

[a] This table lists all known assemblages with pronghorn MNI > 5, and pronghorn MNI > 50% of total MNL Fetal material has been excluded from pronghorn MNI as possible. Radiocarbon ages averaged with Long and Rippeteau's (1974) method.

[b] Unknown (could not be determined from reported data).

[c] Based on the 1985 excavations (Lippincott 1996); the 1948-1950 excavations produced 15 MNI ma ture and 6 MNI immature pronghorn (Wheeler 1996).

ledger drawings from 1876-77 record three women and two men riding down a herd of five Pronghorn and deer, and twenty-eight separate images of what are most likely pronghorn appear in rock art from the Black Hills area alone (Sundstrom, 2000).

The antiquity of these communal hunts is highlighted by the large number of, and vast area covered by, archaeological sites, which are interpreted as communal Pronghorn kills (Figure. 3.5-1). In the Wyoming Basin alone, 'Pronghorn remains occur in 67% of all radiocarbon dated assemblages with 10 or more genus level identified bones' (Lubinski, 2000: 165). Sites such as the Barnett and Laidlaw sites in south eastern Alberta provide good evidence that communal hunting is not a phenomenon of the recent past, and, as illustrated in Figure. 3.5-2, has a long history of use for procuring Pronghorn (Brink, 2013; Davis *et al.*, 2000; Frison, 1971; Lubinski, 1999; Wilke, 2013). While evidence of Paleoindian methods of procuring Pronghorn is less distinct than in later times, the fact that they were hunted is obvious from the faunal record. Sites such as Agate Basin in eastern Wyoming contain the remains of five Pronghorn in the Folsom component. The Lindenmeier site in northern Colorado contains a small number, and one ulna was retrieved from the Colby Mammoth site. The Folsom component where these remains were found date to approximately 10,800 BP Frison, 2004: 141).

Genetic Research

This species has changed very little, if at all, since the end of the last ice age, to the extent that even very early specimens from Clovis components show no difference in size compared to modern individuals (Frison, 2004: 141-142). Based on this faunal evidence, genetic research was deemed of limited importance in selection of Pronghorn in the sample collection for the author's research.

Feasibility of Sourcing Skin

Easy, large population, extensively hunted, no restrictions on possession.

Bighorn Sheep (Ovis canadensis)

Name:	Bighorn Sheep (*Ovis canadensis*)	
Also known as:	Mountain Sheep	
Physical Characteristics:	Sexual Dimorphism: Males are larger than females.	
	Males	**Females**
Length:	1.6-1.9 m (5.2-6.2 ft)	1.6-1.7 m (5.2-5.6 ft)
Weight:	75-135 kg (165-298 lbs)	48-85 kg (106-187 lbs)
Pelage:	Reddish to dark brown above with white rump, belly and inside of the legs. The short tail is always dark in colour. (http://www.mnh.si.edu/mna/main.cfm)	

Prehistoric and Modern Range

Historically, bighorn sheep ranged from Peace River in Central Alberta south to Northern Mexico, inhabiting anywhere which contained the mix of the rugged rocky terrain the species prefers. Bighorn once ranged much further east than is often considered prime habitat, primarily in badland areas along major river drainages (Shackleton, 1985). One subspecies (*O. auduboni*) occupied areas of the Black Hills in South Dakota until late in the 19th century (DeBoer, 2004). Today, the range is more limited, though many areas have had the species reintroduced with some success. A desert subspecies (*Ovis canadensis nelsoni*) inhabits lower elevation arid hills in the Southwest, and the closely related dall sheep (*Ovis dalli)* inhabit Alaska and north western Canada (Matheny *et al.*, 1997; Shackleton, 1985).

Habitat Preference and Behavioural Characteristics

Bighorn sheep are shy, elusive animals that live in rough, rocky and inaccessible terrain. They are diurnal and exhibit a cycle of feeding followed by rest and rumination intervals (Shackleton, 1985). They can subsist on multiple forage types, but are primarily grazers, and can be in direct completion with elk and even domestic livestock when their winter ranges overlap (Shackleton, 1985). They are escape specialists and seldom stray more than 300 meters (100 ft) from a cliff face (Matheny *et al.*, 1997). When threatened, they can clamber up such a cliff with apparent ease. Bighorn have powerful, stocky bodies, good eyesight and specially adapted cloven hooves, which make them excellent at leaping and climbing but poor runners when compared to deer, elk and pronghorn; so much so that a human can outrun a bighorn on level terrain (Matheny *et al.*, 1997; Nowak, 1991). They use these adaptations to out-manoeuvre predators, which consist primarily of coyotes and cougars, as well as wolves, which have been successfully reintroduced into wilderness areas south of the Canadian border (Frison, 2004: 152).

The herds, which separate into male and female groups for much of the year, migrate seasonally, moving to lower elevations when the snow becomes deep enough to hinder foraging (Judson *et al.*, 2005; Matheny *et al.*, 1997; Osborn, 1993; Shackleton, 1985). During the fall rut the rams re-join the ewe and lamb herds, losing much of their typical wariness in the drive to secure females. The rams are well known for their dominance displays during the rut, rearing up on their hind legs, kicking with their front legs and clashing their horns together. Though their skulls are well designed for the impact of these displays, injury is not uncommon (Matheny *et al.*, 1997; Shackleton, 1985). Lambs are born in spring, often on an inaccessible ledge, and can remain isolated with their mothers for up to a week. This strategy may allow for strong maternal bonds to develop, as well as provide some reduction in thermal stress for the new lamb (Matheny *et al.*, 1997). Lambs can, however, follow their mother within a day if necessary (Frison, 2004: 151).

Hunting Strategies

Bighorn Sheep congregate in herds and when chased will run as a unit. This behaviour, as well as their seasonal migrations, were exploited by Native hunters who constructed large traps into which the sheep were driven. The amount of labour needed to haul large trees, at elevations of 2,100 to 4,000 meters (6,889-13,123 feet) in very rough country, highlights the importance and probable success of this type of hunting (Driver, 1982; Garfinkel *et al.*, 2010; Matheny *et al.*, 1997; McGuire and Hatoff, 1991; Smith, 2013). Based on a lack of osteological evidence within or around the traps, it seems likely that animals were butchered elsewhere (Driver, 1982; McGuire and Hatoff, 1991; Smith, 2013). The average live weight of a bighorn sheep, from approximately 60 pounds (27 kg) as a lamb to 162 pounds (73.5 kg) for an adult male, is, after field dressing, a manageable weight to carry back to a base camp as a whole carcass. The lack of projectile points found in these traps, combined with the few pieces of wood interpreted as clubs and ethnographic accounts point toward clubbing as the probable method of dispatch (Frison, 2004; 1971). Looking at today's bighorn population might make one question the feasibility of driving enough animals to make this a worthwhile endeavour, but according to accounts from early explorers and trappers in these areas, bighorn

Site	Location	Date	Finds	Reference
Gatecliff Shelter	Central Nevada	1250 C.E.	20 MNI	Frison 2004
Sheep Mountain	North West Wyoming	8,800 BP	Cordage net	Frison 2004
Pagoda Site	North West Wyoming	3,000 BP	Bugas Holding trap	Frison 2004
Ruby Valley	Central Nevada	undated	Well preserved trap	Frison 2004
Mummy Cave	North West Wyoming	9,000-400 BP	Bighorn present in all cultural levels	Frison 2004
Rose Hill	South East California	500 BC – 300 AD	Bighorn and Pronghorn dominant species	Garfinkel *et. al.* 2010
White Mountains	S.E. California Compilation of 75 sites	1500 BC – Historic	Bighorn and Marmot dominant species	Garfinkel *et. al.* 2010
Olsen Site	North Central Colorado	1881 BC – 1869 AD	3 MNI with an extensive trap, and blinds	LaBelle 2013
Mount Augusta Site	Central Nevada	3000 BC – 700 AD	At least 3 MNI and trap which likely used nets	McGuire 1991
Nine Mile Canyon	Eastern Utah	Archaic – 1800's	Rock art panels and skin fragment	Metheny 1997
DjPo-47	Crows Nest Pass, Alberta	8,500 BP	3 MNI with cut marks and an extensive trap	Driver 1982
48PA3147.5 48PA3147.15	Greater Yellowstone Area	2318-1552 BP	Cut marked bone and shaft fragments	Lee 2012

Figure. 3.5-3. Sites Which Highlight Utilization of Big Horn Sheep.

sheep were very populous before hunting pressure in the late 1800s and early 1900s severely reduced their numbers (Frison, 1971).Two types of traps for mass capture have been identified by Frison (2004: 158); the first consisting of wings or drive lines, culminating in a catch pen, and the second using similar drive lines, but terminating in a holding pen, from which individual animals could be driven into smaller catch pens . As would be expected, most of these traps are found in alpine areas and usually encompass some natural landscape formation that already directs the herds into the general vicinity of the drive lines (Driver, 1982; Frison, 2004; McGuire and Hatoff, 1991; LaBelle and Pelton, 2013).

Of course, bighorns were also hunted as single individuals or in small groups by hunters, either using blinds placed at strategic points to take advantage of migration behaviour, or simply moving from one valley to the next over the many narrow passes present in this type of terrain (Frison, 2004; Garfinkel *et al.*, 2010; Gilreath and Hildebrandt, 2008; Matheny *et al.*, 1997). There is also a reasonable amount of evidence to suggest that small groups were netted and clubbed at these strategic choke points (Frison, 2004; Matheny *et al.*, 1997; McGuire and Hatoff, 1991)

Archaeological and Ethnographic Prevalence and Support

Bighorn appear in a number of ways in the archaeological record. They are well-represented in excavated faunal remains found over a large area west of the Great Plains from Canada to Mexico, as are trapping complexes at high elevations which are attributed to their pursuit and capture (Driver, 1982; Frison, 2004; Garfinkel *et al.*, 2010; Judson *et al.*, 2005; Lee, 2012; Matheny *et al.*, 1997; McGuire and Hatoff, 1991; Osborn, 1993; Pippin, 1979). They appear frequently in rock art images, not just as individual symbols but in complex hunting scenes and as images on pottery and pipe stems as far east as Florida (DeBoer, 2004; Garfinkel *et al.*, 2010; Gilreath and Hildebrandt, 2008; Matheny *et al.*, 1997). A notable piece of direct evidence for use of the skin prehistorically was found in a dry cave site, which preserved a tanned hide fragment. This fragment was recovered and analysed for DNA, which showed it was indeed bighorn sheep skin (Matheny *et al.*, 1997; Lee, 2012). There have been numerous ethnographic accounts of their use by various Native American groups (DeBoer, 2004; Matheny *et al.*, 1997). While Figure. 3.5-3 gives a general overview of sites containing bighorn sheep remains, some areas of intensive use or unusual preservation are worth mentioning on an individual basis.

Nine Mile Canyon in central eastern Utah is a large side canyon through which flows a tributary creek of the Green River. The canyon contains a wealth of rock art, which spans a time continuum from at least the Archaic through to the arrival and settlement by Euro Americans in the late 1800s (Matheny *et al.*, 1997). The canyon contains hundreds of depictions of bighorn sheep which range in complexity from single individuals (often shown with arrows or darts in flight or embedded in the animal) to large detailed hunting scenes containing numerous individuals. One such large panel contains thirty-six bighorn, with at least five hunters holding drawn bows with arrows pointed toward the oncoming herd. What is interesting to note, aside from the beautiful artwork, is the artist's obvious knowledge of hunting strategies in regard to bighorn behaviour.

The herd consists of a line of rams paralleled by two lines of ewes with lambs: a type of formation bighorn often walk in when moving from one feeding area to another (Matheny *et al.*, 1997). The composition of the herd also indicates that it was common practice to hunt during the fall rut, when the rams mixed back in with ewes, lambs, and yearlings. This is in keeping with theorized hunting strategies, which take advantage of the larger herd size and lowered awareness level of rams at this time of year (Driver, 1982; Frison, 2004; Matheny *et al.*, 1997; McGuire and Hatoff, 1991). In keeping with the time depth of the area's occupation various panels show both atlatl and bows in use, both in pursuit of single animals and in narrative hunting scenes. In addition to the wealth of rock art, Nine Mile canyon also produced the small fragment of skin that was analysed for DNA and found to be from a bighorn sheep (Matheny *et al.*, 1997).

Another notable area where bighorn appear to have played an important role in the everyday lives of the inhabitants is the Coso Range of eastern California. In this area of basalt lowlands, interspersed with piñon-juniper uplands, Native American inhabitants produced over 100,000 rock art sites, one of the densest concentrations in the country. Over 50,000 of these depict bighorn sheep (Garfinkel *et al.*, 2010). The area has been inhabited since the Paleoindian period, though the majority of the artwork dates to between 2000-1500 BC and AD 1300, as evidenced by the use of both atlatls and bows in panels of various ages (Garfinkel *et al.*, 2010; Gilreath and Hildebrandt, 2008). Based on seventy-five sites in the area, bighorn and pronghorn (*Antilocapridae americana*) dominate the faunal remains at low elevation sites such as Rose Spring, and bighorn and marmots (*Marmota flaviventris*) comprise the majority of remains at high elevation sites, including twelve hunting camps in the White Mountains (Garfinkel *et al.*, 2010). Though this dependence appears to vary in relation to relative population abundance of prey species, during the Newbury Period, (1500 BC-AD 300) bighorn remains exceed deer fifty to one (Gilreath and Hildebrandt, 2008). This reliance is not limited to isolated areas of the west, as 'Faunal records from dated archaeological sites indicate bighorn sheep were an important and consistent Great Basin prehistoric resource. Bighorn were the preferred game resource by the occupants of Humbolt Cave, Wagon Jack Shelter, South Fork Shelter, Weston Canyon Rockshelter, Deer Creek Cave, Snake Rock Village and Catlow Cave number 1.' (Pippin, 1979: 33).

In the high country of the Rocky Mountains to the east of the Great Basin a number of remarkable finds which most likely relate to hunting bighorn have been recovered. Though global warming is generally perceived to be a destructive trend for archaeology in high mountain areas, its effect has uncovered some notable finds as reported by Lee (2012), including a dart shaft dated to 10,400 BP. The shaft was found at an elevation of 10,561 feet (3,219 meters) above sea level in a retreating ice patch in the Greater Yellowstone Ecosystem. More recent dart fragments date to 7500 cal BP found in relation to cut marked bone consistent with bighorn sheep morphology indicate the likely prey species (Lee, 2012). In the same general area Frison (2004: 159) notes large mature ram skulls with the foramen magnum smashed in, which were often left in forked trees; activity he attributes to shamanistic activity. It is possible also, to view this as evidence for use of the brain for tanning purposes, removed in a way that would not damage the showy part of the skulls, which were then placed in the trees.

Perhaps an even rarer find was recovered by hikers from a dry cave on Sheep Mountain above Cody Wyoming. The unusual mound of cordage when unrolled turned out to be a net, 50-65 meters long by 1.5-2 meters high (165.5-213 feet by 5-6.5 feet), made from Juniper (*Juniperus sp*) bark. The diameter of the cordage varied from 1.0-5.2 millimetres in diameter (.04-.2 inches) and was dated to 8800 cal. BP, placing it during the late Paleoindian period (Frison 2004: 165). Frison (2004) postulates that the net would have been sufficiently strong to net bighorn sheep and was cached in the dry cave for use during the fall and spring migrations which passed through the area. Mummy Cave, a site in the same drainage as the Sheep Mountain net, gives further evidence of the importance of bighorn sheep as a prey species in the region. All twenty-nine of the cultural levels excavated, which range in age from 9000-400 BP, yielded bighorn sheep remains as well as another fragment of net, similar to the complete net found that dates to the late Archaic (Frison, 2004: 166). 'Overall, the archaeological evidence in the Greater Yellowstone Ecosystem, although relatively limited, indicates continuity of mountain sheep procurement for more than 10,000 years.' (Frison, 2004: 168).

Though accounts of actual hunts are rare, there are a number of ethnographic mentions of bighorn products being used by local groups. Lewis and Clark make mention of spoons made from bighorn sheep horn, traded to them by the Shoshone (DeBoer, 2004). Jedediah Smith, an early fur trapper, and later guide recorded the Ute using bighorn sheep hides for clothing and the horns for composite bows backed with sinew. Other ethnographic reports mention the Northern and Gosiute Shoshone and the Northern Paiute using the skins and horns as well (Matheny *et al.*, 1997).

These early explorers were not the first people from outside of bighorn terrain to be intrigued by this memorable animal. At Mound City on the Scioto River, far to the east of the Rocky Mountains, an effigy pipe that appears to be a depiction of a bighorn ram was recovered. In a grave from the same site what certainly looks like a copper sculpture of a ewe's horn was also recovered. This, when added to a large amount of obsidian, which originated from Obsidian Cliff in present-day Yellowstone Park and some even further west from Bear Gulch Idaho, have been interpreted as the result of a trading trip embarked on by some ambitious group, hoping to take advantage of the interest in exotic goods by the well-to-do families of Mound City (DeBoer, 2004). They brought back not only commodities but descriptions of unfamiliar animals that made their way into artwork, probably dating to 100-300 AD (DeBoer, 2004).

Genetic Research

Bighorn sheep remains from over thirty late Pleistocene sites have been recorded across western North America. Though specimens dating before 10,000 BP are slightly larger than modern examples it is widely acknowledged that, since this date, bighorn have changed very little (Shackleton, 1985). Based on the consistency of the faunal record, genetic analysis and interpretation was not a priority for choosing a variety of bighorn for this project.

Feasibility of Sourcing Skin

Difficult, trophy animal, small population, very few licenses given.

Elk (Cervus canadensis)

Name:	Elk (*Cervus canadensis)*	
Also known as:	Wapiti	
Physical Characteristics:	Sexual Dimorphism: Males are larger than females.	
	Males	**Females**
Length:	Average: 2.4 m (7.9 ft) Range: 2.1-2.6 m (6.9-8.5 ft)	Average: 2.2 m (7.2 ft) Range: 2-2.5 m (6.6-8.2 ft)
Weight:	Average: 331 kg (730 lbs) Range: 178-497 kg (412.3-1096 lbs)	Average: 241 kg (531 lbs) Range: 171-292 kg (377-643.8 lbs)
Pelage:	(http://www.mnh.si.edu/mna/main.cfm)	

The bulls grow impressive antlers with six or more tines that can reach more than 2 meters (6.6 ft) in length, which they use to impress cows, as well as fend off rival males during the fall breeding season or rut (Nowak, 1991: 1380).

Prehistoric and Modern Range

Herds of wild elk today are found west of the Missouri River, with the largest concentrations occupying the Rocky Mountain corridor from Canada to New Mexico, at the southern edge of their range. Prehistorically, elk were found over a much larger swathe of North America, with the northern boundary possibly extending into present day Alaska, and the southern extreme reaching into Louisiana and Alabama (Curren, 1977; Holmes, 2001). The range extended to the Pacific Ocean in the west, and through the entirety of the Great Plains into the Appalachian Mountains in the east. This extensive geographic range shrank somewhat, beginning 2500 years ago, vacating its southern most zones (Curren, 1977). Though no longer found on the plains, according to historical reports, elk were once a frequently encountered plains animal (Frison, 2004; Molloy, 1993). As happened with much of North America's big game, over-hunting and habitat loss reduced the numbers of elk to a remnant population by the late 1800s, which survived in the remote areas of Yellowstone National Park and the Jackson Hole area of Wyoming (Frison, 2004: 179). Elk have since been reintroduced into many parts of the west, and today are again quite numerous. In Yellowstone, the herds have grown so large in size that they and the neighbouring bison herds have begun to negatively affect the surrounding environment. The introduction of grey wolves into Yellowstone has been undertaken as a population control measure, since wolves prey on large numbers of elk and bison calves, as well as sick, elderly or unlucky individuals trapped by heavy winter snow.

Habitat Preference and Behavioural Characteristics

Elk are highly gregarious and will form large herds led by a dominant female, which, for most of the year, are predominately single sex (Altmann, 1951). During the fall rut, the males re-join the calf-cow herds in search of mating opportunities. It is during this season that the bull's distinctive whistling call, the 'bugle', can be heard in many areas of the west. In some areas, elk migrate to higher ground during the summer, and return to lower elevations in the fall. However, historical accounts for eastern elk herds record that groups in these areas did not migrate (Nowak, 1991: 1381).

Elk's diet is varied, and both grazing and browsing have been observed, extending to eating the tips of conifers during lean winter months (Nelson and Leege, 1982). The cows will isolate themselves for several weeks after birthing their calves, then return to the herd, which during summer can reach several hundred individuals (Altmann, 1951).

Hunting Strategies

These large summer herds were a behavioural characteristic likely used to advantage by indigenous hunters. There is one eyewitness account of a group of Arapaho driving an Elk herd over a cliff somewhere near the Black Hills in South Dakota (Grinnell, 1923: 1276 in Frison, 2004: 184). In addition to grouping, elk have very regular diurnal behaviour patterns, which could be used to a single hunter's advantage. The groups often bed down during the middle of the day in dense forest or scrub thickets, where they can often be located by their distinctive smell (Frison, 2004: 179).

There have been no trapping complexes identified that specifically target this species. It appears that these animals were mostly taken with single procurement strategies or, as with the ethnographic account, groups were driven over cliffs at jump sites, similar to what has been described for bison.

Prevalence in the Archaeological Record

Despite the species large geographic distribution, elk appear less frequently in the faunal record than do deer, bison, pronghorn, or bighorn sheep (Curren, 1977; Lyman and Wolverton, 2002; Osborn, 1993; Parmalee, 1962; R. Lee, 2005). During the Paleoindian period in the Rocky Mountain region, the stronghold of today's modern elk population, elk antler appears more often than bone in the archaeological record, and is often recovered in the form of tools such as: digging tools at stone quarry sites, flaking or percussion billets for flint knapping, atlatl components and much later, during the late prehistoric, as L-shaped hide scraping handles, and saddle components (Frison, 2004: 182). When the Great Plains are included into the faunal percentages, elk make more of an appearance, making up 8% of the bone recovered from 69 sites in the Rocky Mountains and Great Plains (Hill Jr, 2008).

While overall elk appear to play a background role in hunting preferences, there are areas where they were more intensively pursued. In the Pacific Northwest, elk appear more frequently in the archaeological record. Though they never match the number of deer or pronghorn elements recovered, in a number of sites from the Washington-Idaho border, they do comprise the third-largest proportion of large artiodactyls recovered (Lyman and Wolverton, 2002). Though not in large numbers, elk remains are represented in areas as far distant as present-day California, Alabama, and Alaska (Curren, 1977; Holmes, 2001).

The smaller percentage of use seen in the archaeological record is surprising, given that an elk represents a large amount of calories and other resources, with the average weight for a field dressed female being 160 to 180 kg (353-397 pounds), with a male weighing 10 to 20% more (Frison, 2004: 181). This bias could be a reflection of a food preference, as the ethnographic record is 'peppered' with references to the unpleasant taste and consistency of elk fat (Kay, 1998). However, the author has eaten elk meat on numerous occasions and found no fault with taste or texture. The lack of osteological components for a species in the archaeological record does not necessarily mean that a species was not utilised. Just because elk was a less favoured culinary item, does not mean the species did not provide other items of use. Based on the presence of processed skin artefacts identified as elk, in the catalogues of both the Smithsonian National Museum of Natural History and the History Colorado collections, the skins were most certainly being used. This is unsurprising, considering a sizeable skin can be attained from elk, which is of intermediate thickness, between a bison and deer skin.

A second example of a non-food-based use of an elk product is the use of the canine teeth, also called whistlers, ivories, or tusks (Frison, 2004: 179). Historic accounts by traders mention their use by the Mandan, Hidatsa, Crow, Blackfoot, Dakota, and a variety of other tribes further west, as both adornment and form of currency (Balfour, 1890). They are a distinctly feminine form of decoration, and a dress which requires 300 teeth was, at the time (late 1800s), worth $200 or eight horses (Wood, 1957). Each elk has only two of these teeth, and a dress which takes 150 individuals to decorate makes a convincing argument for the utilisation of significant numbers of elk in some areas of North America, even if they are under-represented in the archaeological record in relation to other species. Though this type of decorative style appears to be mainly a Plains phenomenon, perforated elk canines have been recovered archaeologically from as far east as Frontenac Island, New York, where a pair were found in a burial context (Wood, 1957: 383).

The decision to include elk in the sample collection was made based on the vast geographical area which this species inhabited over the past 10,000 years, in spite of making up only moderate percentages of the faunal record. The species' continuous, if low, profile presence in the faunal record, alongside its confirmed existence in recovered processed skin artefacts and historical accounts documenting the value placed on its teeth, made this species a necessary inclusion in the comparative collection.

Genetic Research

Based on faunal evidence, elk has undergone no significant change within the time frame relevant to this research. As mentioned in the red deer discussion in section 3.3, elk and red deer are very closely related, but based on MtDNA are deserving of their own sub species statuses of *canadensis* and *elaphus*, and both have been included in the comparative collection (Jansen *et al.*, 2002).

Feasibility of Sourcing Skin

Relatively easy, fair number of hunting licenses available and elk are often victims of traffic encounters.

3.6 Introduction to Transcontinental Species Selection

The major points covering key factors, such as the frequency of a species in the archaeological record through time, their spatial distribution both prehistorically and historically, ethnographic accounts of species targeted in the past, and the feasibility of acquiring a skin, have been explained in the previous introduction section for North America and Europe. However, a few species were not isolated geographically on one continent or the other. Moose, reindeer and a large majority of the traditional furbearing species spanned the entirety of both of these geographical regions. However, a few points are worth reiterating, or adjusting slightly for what are primarily arctic and subarctic species.

As many of the areas currently inhabited by these transcontinental species still have traditional groups living in and utilising these environments, or did within historic memory, ethnographic evidence was more heavily relied upon than for some previously discussed species. The issues of domestication are again raised for reindeer, dog, and rabbit, which have been acquired using drastically different strategies through time. Though these strategies are not strictly linear, and vary by location, and in response to climatic factors, and have often been used simultaneously. Genetic data was reviewed in light of choosing varieties or breeds of these species but played a smaller role than in choosing varieties of the more traditional domestic species such as cattle, sheep and goats. Rock art showing the selected species as individuals and in relation to hunting scenes was reviewed and, again, a preference was shown toward species identified from extant archaeologically recovered processed skin objects.

In light of these considerations, moose, reindeer/caribou, and selected furbearers were chosen to include in the comparative sample collection. The choice of furbearers was more dependent on the ability to source skins than was the decision for many of the other selected species. Due to this, the furbearers have been combined into a subsection, and talked about as a commodity group, as opposed to being singled out and discussed as individual species, as has been the procedure with previous species. However, Leporid, beaver, bear and dog have additional information mentioned, while moose and reindeer are allotted individual sections in keeping with the procedure thus far.

3.7 Selected Transcontinental Species

Reindeer/Caribou (Rangifer tarandus)

Name:	Reindeer/Caribou (*Rangifer tarandus*)	
Also known as:	Caribú	
Physical Characteristics:	Sexual Dimorphism: Males are larger than females. Reindeer are the only member of the deer family where both sexes have antlers, though those of the males are significantly larger than those the females.	
	Males	**Females**
Length:	Average: 1.8 m (5.9 ft) Range: 1.6-2.1 m (5.3-6.9 ft)	Average: 1.7 m (5.6 ft) Range: 1.4-1.9 m (4.6-6.2 ft)
Weight:	Average: 110 kg (242.5 lbs) Range: 81-153 kg (178.5-337.3 lbs)	Average: 81 kg (178.5 lbs) Range: 63-94 kg (138.9-207.2 lbs)
Pelage:	In summer, the coat is typically a dark grey-brown with lighter bellies, inner legs, and buttocks. The coat lightens during the winter months, with some varieties such as those on Ellesmere Island being almost pure white (Nowak, 1991: 1397). (http://www.mnh.si.edu/mna/main.cfm)	

Prehistoric and Modern Range

The historic range of reindeer is substantial, and covered the entirety of the circumpolar artic, sub-arctic and northern boreal zones, including Scotland, Ireland, and Greenland (Nowak, 1991: 1399). In North America, the species ranged as far south as the extreme northern portions of the lower 48 states, from Maine to Washington. Interestingly, historical accounts exist for its presence in southern Idaho in the early 1800's in the United States (Nowak, 1991). During the Pleistocene, the reindeer's range extended as far south as Nevada in the continental United States, and, during the Magdalenian, inhabited areas as far south as northern Spain and south west France in Europe (Müller-Wille *et al.*, 2006; Macdonald, 2005). In Europe, populations of reindeer survived in Germany until Roman times, the British Isles until the Medieval Ages, and in Poland until the 1500's (Nowak, 1991: 1398).

This decline in habitat has continued into modern times, where reindeer are now absent from much of their historic and prehistoric range. In Europe, the species is today found only in the far northern parts of Scandinavia, where there is a remnant population of wild reindeer in Norwegian and Swedish Lapland (Macdonald, 2005: 208). Remnant herds of wild reindeer also exist in northern Mongolian and Manchuria, and significant herds still exist across Siberia, though they are often in competition with domestic herds in this region (Nowak, 1991). Reindeer have also been reintroduced to a few isolated parts of Scotland (Macdonald, 2005). In North America, reindeer present in their southernmost range were hunted to extinction by the early 1900's, with the exception of the Selkirk herd of northern Idaho, which still exists into the present day. In the more northern portions of their range, the tundra reindeer have stable populations where they form the largest groups of reindeer in the world. These are called the barren ground herds, the largest of which encompasses up to 600,000 individuals (Nowak, 1991: 1399). However, a neighbouring subspecies, the woodland caribou (*Rangifer tarandus caribou*) – which, as its name suggests, inhabits mature, boreal forest areas – is endangered (Nowak, 1991: 1399).

Habitat Preference and Behavioural Characteristics

Most reindeer herds are found in either Arctic tundra or the adjoining coniferous boreal forests. They are primarily diurnal and rely heavily on their well-developed sense of smell to detect predators, as their hearing and eyesight are less keen. They have broad flat hooves, which allow them to move efficiently even in deep snow and marshy ground created during summer as the top layer of the permafrost melts. They have been recorded running at speeds between 60-80 km/h (37-50 mph) (Nowak, 1991: 1397).

With the exception of the Woodland subspecies, reindeer are highly gregarious and form migration herds in the tens of thousands (Burch, 1972). These herds disperse to smaller groups in the summer led by an older female (Macdonald, 2005). The groups are single sex for most of the year, consisting of females and calves, with bachelor herds moving around the landscape separately, except during rut when the males collect harems (Sommerseth, 2011). The migratory patterns for reindeer vary depending on the subspecies and the terrain, with the tundra reindeer being more migratory than the forest or woodland reindeer (Burch, 1972). Many of the northern tundra herds make extensive migrations, which can cover up to 1,000 km (621 miles) between summer and winter ranges, with the most extreme example being the George Herd of the Ungava Peninsula, which covers 500,000 kilometres (310,686 miles) annually (Nowak, 1991; Macdonald, 2005; Madsen). Forest populations, by contrast, can have summer and winter ranges which overlap significantly and may cover only a few hundred kilometres (60-120 miles) in a year (Madsen). Both sedentary and migratory herds seek out snow patches, windy ridgelines and even lakes during peak insect season, in an effort to avoid the worst of the mosquitoes, black flies and midges which torment the herds during the summer months (Sommerseth, 2011; Burch, 1972).

Reindeer eat a variety of plants, but rely heavily in many areas on lichen, which is their main winter forage, though grasses, sedges, and mushrooms also form a significant portion of their summer diet (Madsen; Macdonald, 2005; Sommerseth, 2011). Reindeer are ruminants, so after foraging will spend periods of time lying down to chew their cud (Burch, 1972).

Utilisation Strategies

Reindeer have played an important role in the history of hunting around the world. They have been a critical resource for tens of thousands of years for groups living in the circumpolar regions, providing numerous animal products necessary for human survival in cold climates (Friesen, 2013). This importance reflected in the variety of ways in which this species was acquired. Solitary stalking along with snares, pit traps, and communal drives were all means of taking wild reindeer in the past (Burch, 1972; Friesen, 2013; Müller-Wille *et al.*, 2006; Sommerseth, 2011).

Burch (1972: 346) breaks these hunting strategies down into two basic categories, which in the pre-rifle period have been employed 'with remarkable homogeneity' throughout the vast area occupied by both reindeer and humans. The 'Search and destroy' strategy encompasses most of the solitary stalking techniques, and requires an in-depth knowledge of reindeer behaviour, as well as their seasonal patterns. This technique is most successful at times of year when the animals are more sedentary or using the insect harassment mitigation strategies mentioned earlier. Snow patches and windy ridgelines are relatively geographically fixed, and hunters with knowledge of these areas can acquire animals with a fair regularity. The 'Head-'em-off-at-the-pass' strategy is probably the most frequently used option for reindeer, as they have very predictable migrations, as well as reactionary behaviours to predators and predator calls, such as the howls of wolves when mimicked. These howls are used with good effect, in driving herds along drive lines and into corrals (Friesen, 2013: 22.). However, one still needs a large amount of knowledge – not only of reindeer migratory behaviour, but also about the general landscape they inhabit, to successfully choose which pass to 'head-off'. In addition to an extensive knowledge base, drives required a concentrated effort by an entire group of people, and Friesen (2013) breaks this hunting strategy down further, into terrestrial and aquatic categories. The terrestrial hunts relied on drive lines made of stone cairns, called 'inuksuit', which helped to direct a herd into either an enclosure, or past shallow depressions used as hunting blinds called 'taliut'. While in the water, the Inuit hunters in kayaks would wait for the reindeer to be driven into the sea, lake or river, where they could then be dispatched using lances (Friesen, 2013: 14).

In some areas of the world, the hunting of wild reindeer gradually changed to a basis of pastoral herd management, and then into true domestication through time (Sommerseth, 2011). Reindeer herding is thought to have originated east of the Ural Mountains a few thousand years ago, then spread to other areas of Eurasia. However, recent mtDNA analysis of both domestic and wild reindeer populations across this region instead suggest two, and likely three, independent domestication events: one in eastern Russian, one in western Russia, and one in Fennoscandia (Røed *et al.*, 2008). These domesticated herds are managed for meat, hides, bone, antler velvet, milk and as a means of pulling sleds during the winter months and carrying packs during the summer months (Røed *et al.*, 2008; Sommerseth, 2011).

Prevalence in the Archaeological Record

Reindeer remains make up a large portion of the faunal record for various parts of Europe and North America through time, beginning long before the earliest time bracket for this research (Bratlund, 1996; Atle Nesje, 2011; Burch, 1972; Costamagno *et al.*, 2006; Friesen, 2013; Müller-Wille *et al.*, 2006; Sommerseth, 2011; Sturdy, 1975). These finds occur from two important use strategies: the hunting of wild reindeer across the entire circumpolar region, and in some areas from the utilisation of domesticated reindeer herds. Throughout the Late Glacial of northern Europe, reindeer elements, especially antler, are the 'most frequently reported mammalian finds in the area' (Bratlund, 1996: 7). All through western and central Europe during this period, large numbers of reindeer remains indicate this was an important prey species, in some areas comprising 99% of the faunal remains (Müller-Wille *et al.*, 2006). The archaeology of the interior of Eurasia supports a similar reliance on reindeer as a key prey species through the terminal Pleistocene and through the Holocene (Golovnev and Michael, 1992; Pitul'ko, 1999). The Faunal record of northern North America shows a similar trend, with groups living in the interior regions relying heavily on reindeer as a prey species, while coastal groups focused more on marine resources (Fagan, 1991: 139-182; Nelson, 1986: 113-114). However, these coastal groups, at contact, had extensive trade relations with interior groups, with reindeer skins being a sought-after trade item for making warm clothing (Nelson, 1986; Burch, 1972; Golovnev and Michael, 1992).

There is an ethnographic preference for fall skins, when the hair is not too thick (making it too warm to wear), and when the skins are not riddled with holes from emerging bot fly larva (Dean, 2008). While some of the animal was eaten, this time of year was too warm to preserve much of the meat, and the hunt was primarily undertaken to acquire skins (Burch, 1972: 362). This 'hunting for hides' strategy has been mentioned for other areas of the world, including the Great Plains in relation to bison hide shields (LeBlanc, 1999), the east coast for deer skins (Gramly, 1977; Turner and Santley, 1979; Webster, 1979), and proposed as an answer to the unusual number of gazelle being hunted in the Near East using large scale drive lines and enclosures (Smith, 2013). These corrals and drive lines are not limited to the Near East, and, as previously mentioned, were used extensively in the North American Arctic. In these regions they are highly visible due to the slow formation of soil, and are an ubiquitous part of the Arctic landscape (Friesen, 2013: 15). In the more forested areas of northern Europe, large numbers of pit fall traps for reindeer can be found – in particular in the northern Fennoscandian region, where this type of type of trapping strategy may have been established as early as 2600 BC (Sommerseth, 2011). In addition to the physical remains of the pit trapping system, corrals with long funnel shaped fence systems for capturing reindeer are depicted in rock art in Alta and date to around 5200-4200 BC (Sommerseth, 2011: 15).

As glaciers and snow patches continue to recede in high elevation and high latitude areas of the world, many artefacts thought to be associated with hunting reindeer, who use these areas to escape insects, have emerged. Scare sticks used in the same way as rock cairns are for drive lines, bows, arrows, dart shafts and points, as well as reindeer remains, have been found (Atle Nesje, 2011; Sommerseth, 2011; Reckin, 2013; Dixon *et al.*, 2005).

From an ethnographic standpoint, reindeer skins are an incredibly important part of the circumpolar survival strategy. The nearly ubiquitous use of reindeer, both with the hair left or with it removed, in literature dealing with ethnographic clothing construction for Arctic and subarctic regions, firmly supports the use of this material back into history and prehistory (King, 2005; Pitul'ko and Kasparov, 1996; Oakes and Riewe, 1995; Issenman, 2011). This, in addition to the heavy utilisation of this species implied by the faunal record over a tremendous geographical area and vast time frame, mean that reindeer 'may well be the species of single greatest importance in the entire Anthropological literature on hunting' (Burch, 1972: 339). In light of this, this was deemed a very important species to include in the comparative collection.

Genetic Research

As with the other wild species, the use of wild reindeer has continued into the present time, and, based on the faunal record, the species appears to have changed little within the time frame covered by this research. In addition, the genetic research showed a short domestication period for the species, during which the domestic population was supplemented with wild stock, making the morphology of domestic reindeer very similar to that of wild reindeer (Røed *et al.*, 2008).

Feasibility of Sourcing Skin

Moderately difficult, in that reindeer are not available in the area in which the research took place, nor in the western United States, where many of the author's hide sources were located. However, an experienced tanner from Sweden, Lotta Rahme, kindly provided a portion of an untanned domestic reindeer skin (http://www.lottasgarveri.se/English.html).

Moose (Alces alces)

Name:	Moose (*Alces alces*)	
Also known as:	Elk in parts of Europe	
Physical Characteristics:	Sexual Dimorphism: Males larger than females. Massive palmate antlers in males	
	Males	**Females**
Length:	Average: 3.1 m (10.2 ft) Range: 2.5-3.2 m (8.2-10.5 ft)	Average: 3.1 m (10.2 ft) Range: 2.4-3.1 m (7.9-10.2 ft)
Weight: They are the largest member of the deer family	Average: 430 kg (948 lbs) Range: 360-600 kg (794-1323 lbs)	Average: 350 kg (772 lbs) Range: 270-400 kg (595-882 lbs)
Pelage:	The body is dark greyish brown, with lighter grey to white legs. They have large ears, a Roman-nosed profile with hairy nose pads, and the males have large, pendulous dewlaps under the lower jaw. The calves are reddish brown and, unlike other members of the deer family, have no spots (Macdonald, 2005: 208). (http://www.mnh.si.edu/mna/main.cfm)	

Prehistoric and Modern Range

Moose were prehistorically, and are still today a circumpolar boreal species, which originally occurred across all northern Europe to the far eastern extremes of Siberia, extending as far south as the Caucasus region. In North America, the species spans the continent from east to west, and is currently found as far south as Colorado and many parts of New England (Nowak, 1991: 1394). Moose are a relatively recent migrant to North America, where they crossed into Alaska approximately 15,000 years ago, though there is paleontological evidence of much greater antiquity in Beringia (Hundertmark *et al.*, 2003). In Europe, the species distribution has shrunk considerably due to hunting pressure and loss of habitat. This caused the species' disappearance from Western Europe (with the exception of the Scandinavian Peninsula) by the 13th century, from the Caucasus region by the early 19th century, and from much of the lower 48 states in North America by the early 1900s (Nowak, 1991: 1396). Though classically believed to have become extinct during the Mesolithic in the British Isles, new evidence supports the species' existence though at least the Bronze Age, and possibly in Scotland into the mid-16th century, when the loss of the beaver (*Castor fibre*) and the marshy habitats they create saw the last of the moose disappear as well (Kitchener, 2010). Today in North America, moose have recolonized much of their historic range through both natural migration and assisted reintroductions.

Habitat Preference and Behavioural Characteristics

Moose are boreal creatures and are especially fond of riparian zones, where they wade through marshy areas to eat aquatic plants. During the winter months they prefer drier ground, where they can more easily access twigs and bark, as well as small forbs buried in the snow (Kitchener, 2010; Macdonald, 2005). Moose are diurnal, with activity peaks at dawn and dusk, and their eyesight is less keenly developed than their sense of smell and hearing, which are both acute. Though awkward-looking, moose can run up to 56 km/h (35 mph) and are strong swimmers. Despite their size and wide hooves, they can move very quietly through the underbrush (Nowak, 1991: 1395).

The migration patterns of moose vary, with some populations moving up to 179 km (111 miles) between home ranges, while other populations are much more stationary in the landscape (Nowak, 1991: 1395). Moose are primarily solitary; however, they sometimes form small aggregates, led by an older female during the winter, becoming concentrated in areas with large amounts of browse (Macdonald, 2005). Moose mate during the fall; when in rut, the males become less wary and tend to gather in greater concentrations in riparian zones, making them easier to locate than during other seasons (Nelson, 1973: 86,). Females take a more active role in the mating process than with most deer species and will call, scent and seek out males (Nowak, 1991). In a similar fashion to reindeer, moose have insect mitigation strategies which they employ to avoid the summer swarms, including habituating mid-river sand bars and deep ponds, where they submerge much of their bodies (Nelson, 1973: 88; Winterhalder, 1981: 80).

Hunting Strategies

Moose are heavily cited in ethnographic literature as the most important game animal in the boreal forest zone. Hunting strategies for solitary big game such as moose rely primarily on individual acquisition strategies, based on intercepting single animals (Helm, 1993; Jarvenpa and Brumbach, 1983a; Winterhalder, 1981; Yesner, 1989; Nelson, 1986). These types of hunting strategies leave little mark in the archaeological record besides the actual faunal remains themselves. Unfortunately, for many of the interior areas of the boreal forest zone even these are rare, as conditions are not conducive to the preservation of organic remains (Yesner, 1989). Therefore, ethnographic examples are heavily relied upon to inform past hunting strategies. The hunting traditions of the subarctic central boreal forests have, based on rare faunal evidence, changed little in North America throughout the Neo-Indian period (1750-250 BP), making these ethnographic observations firmly applicable to at least the late prehistoric and historic era (Nicholson, 1988).

Some luck plays into encountering moose; a fact supported by the ethnographic mention of Cree hunters seldom embarking on a foraging trip, no matter the stated purpose, without .30-.30 rifle capable of killing a moose. Thus, a variety of techniques are employed to increase the odds of a successful hunt (Winterhalder, 1981: 86). Knowing the behaviour and requirements of the prey species over an annual cycle, and how these apply to the territory in which one hunts, significantly increases the chance of locating moose initially. In addition to identifying likely locations for finding moose, the hunter has to get close enough for a lethal shot. Techniques for this vary by season. During the fall rut, specially shaped shoulder blades (scapula) from a cow moose are skilfully rubbed through the bushes to emulate the sound made when a bull rubs his antlers against the underbrush (Nelson, 1973: 93). This sound can cause territorial bulls to charge out intent on confronting a competing male. Conversely, calling by emulating a cow moose can likewise attract amorous bulls (Nelson, 1973: 95).

Driving moose is a second hunting technique, most often employed around islands when the rivers are frozen in winter. This has been documented by Nelson (1973: 107) in the Chalkyitsik region of Alaska, where a group of men would go out together along the frozen river checking each island for moose tracks. When an island with fresh sign is located the men split up, with a few trackers taking to the interior to either shoot or flush out the moose, while the others cover the likely exit routes. In this way, the chances of killing multiple animals, when they are bunched in small winter groups, is increased (Moubarak-Nahra *et al.*, 2014; Nelson, 1986).

Trapping of large species such as moose, deer and elk using snares has been ethnographically documented, and is a highly effective and efficient method of remote hunting (Nelson, 1973: 109). Methods like this are likely underestimated when considering prehistoric hunting strategies, as they are quite foreign to the modern notion of hunting.

As mentioned earlier, great importance is placed on moose hunting in ethnographic texts, at least during certain seasons (Helm, 1993; Jarvenpa and Brumbach, 1983a; Irimoto, 1981). However, many of these areas may have depended more heavily on reindeer prior to the 1800s, especially during the little ice age (1300-1850 AD), when the colder temperatures and higher snow packs would have made it difficult for moose to live in much of the mixed forest/tundra ecotone where they are found today (Yesner, 1989: 98).

Prevalence in the Archaeological Record

While, at least in parts of west central Alaska, the percentage of the diet which came from moose prehistorically can be debated, its presence in the faunal record elsewhere cannot (Kitchener, 2010; Bratlund, 1996; Jessen *et al.*, 2015; Yesner, 1989; Zhulnikov and Kashina, 2010). Moose remains are found in archaeological sites across the Eurasian continent, though the locations of sites with significant amounts of moose move north as the climate warms during the Holocene (Bratlund, 1996; Jessen *et al.*, 2015; Schmölcke and Zachos, 2005). By the Boreal time period, the 'moose-dominated zone (*i.e.* the area in which moose were the most abundant ungulates) was located north of Skåne, Sweden (Schmölcke and Zachos, 2005: 330). In Central Europe, moose remains are found in archaeological contexts north of the Alps from the Late Glacial Palaeolithic through to the Roman/Medieval period, with over 370 securely dated records of moose across the region (Schmölcke and Zachos, 2005: 332).

Not only are moose remains widespread across Northern European archaeological sites, there are numerous instances of direct evidence for hunting these very large deer, in the form of hunting lesions, or even bones with flint points still embedded (Bratlund, 1996; Jessen *et al.*, 2015; Kitchener, 2010). When the standing biomass of moose, in relation to their low population densities, was looked at for the notable Mesolithic site of Star Carr in Yorkshire (UK), moose provided a total food yield higher than that of the numerous red deer present. Based on this, it appears that moose may even have been preferentially hunted over other available ungulates (Kitchener, 2010: 39).

In boreal areas of North America with adequate bone preservation, such as western Manitoba, archaeology from the forest/grassland transition zone shows that moose, along with beaver and migrating waterfowl, were important dietary resources (Nicholson, 1988).

Moose is not only a sought-after source of meat, the large tough hides are valued as well (Young *et al.*, 1991). Many of the moose bones recovered from the Late Mesolithic site of Zamostje in central Russia show evidence of skinning marks (Moubarak-Nahra et. al, 2014: 181). The sequence in which the carcasses at Zamostje were processed closely matches those observed for a modern Athabaskan moose kill documented in 1977, in north-western Saskatchewan (Jarvenpa and Brumbach, 1983b), including loosening the skin from the lower legs with cuts perpendicular to the bone (the motion believed to produce some of the skinning marks seen in archaeological contexts), demonstrating a remarkable level of temporal and spatial continuity of the butchering process. In terms of a historic reference for moose skins as a commodity, Peter the Great felt that these skins produced superior leather, and chose to clothe his army almost exclusively with this material during the early 1700s (Schmölcke and Zachos, 2005: 330). From a tanning perspective, moose skin is large and thick, but has a loose fibre structure, which can produce a vegetable tan with a soft handle. Tanning the skin using fat tanning technologies is also quite feasible, and a soft product can be produced despite its thickness (Kamper, 2016). While there is mention ethnographically of a preference for hunting in the fall and mid-winter for cow moose, ostensibly due to a preference for the meat, there may also be a preference at for these skins, as the skins from adult cows are nearly as large as those of a bull, but considerably thinner and with a more even thickness throughout (Kamper, 2016; Irimoto, 1981; Nelson, 1986; Winterhalder, 1981).

Genetic Research

As with the other wild species, genetic data indicate that moose have not changed significantly within the time frame covered by this research (Hundertmark *et al.*, 2003; Kitchener, 2010). Original moose colonising Alaska were larger than today's moose, however, this size change seems to have happened quite rapidly after colonisation, based on the paleontological evidence (Hundertmark, 2003:724). The European variety of moose found west of the River Yenisi in Russia, and the American variety occurring from eastern Siberia to North America, have somewhat different colourations and different karyotypes, leading some sources to list the American variety as *Alces americana* (Kitchener, 2010: 36). The American variety has four established sub-species, *A. a. gigas, A. a. andersoni, A. a. shirasi, and A. a. americana* (Hundertmark *et al.*, 2003). The skin acquired for the sample collection was of the *shirasi* subspecies found in the Rocky Mountains. It is unknown whether there is a difference in the skin qualities between the different varieties of moose present around the world.

Feasibility of Sourcing Skin

Moderately difficult, as there are a limited amount of licenses issued each year, and skins are often sent away to be tanned by those hunters who make the effort to pack the very heavy skins away from the kill site.

3.8 Furbearer Species Selection

The designation of 'furbearer' is applied to a diverse group of species, usually from the Carnivora and Rodentia orders, which grow a double-layered coat of soft, dense underfur, protected by longer and usually glossy guard hairs. These types of fur are both aesthetically pleasing and warm, and, unlike the hollow hairs grown by deer family (*Cervidae*), furbearers have solid hair shafts which do not break off easily, meaning the pelts look nicer and function better for longer than those from deer. These qualities have made furbearers a valuable commodity historically, shaping trade in northern Europe, indigenous trade in North America, and were a driving force behind colonial expansion in the northern biomes of North America (Cameron, 1998; Howard-Johnston, 1998; Popa and Kern, 2009; Irimoto, 1981; Winterhalder, 1981; Creel, 1991; Pavao-Zuckerman, 2007; Gramly, 1977; Turner and Santley, 1979; Coles, 2010). Based on evidence from numerous archaeological sites and ethnographic sources, furs likely played at least a minor role in the economies of prehistoric groups, as well as providing a necessary thermal material from which to make insulative clothing required for life in northern climates (Gilligan, 2007; 2010; King, 2005; Püntener and Moss, 2010; Charles, 1997; Fairnell and Barrett, 2007a; Irimoto, 1981; Nelson, 1986; Rowley-Conwy, 1995b).

The range of species potentially utilised for their furs across the time span and geographic area covered by this research is extensive. Figure. 3.8-1 demonstrates that nearly every extant species with a pelt is represented in the faunal record somewhere within the project boundaries. These include numerous members of the mustelid, canine, and feline families, as well as the larger rodents such as beaver and muskrat, locally available species such as raccoon, opossum and even domestic dogs and cats. Due to this rather overwhelming variety, the furbearing species were chosen using a somewhat different method than the large game species acquired for this research. After reviewing the generally available archaeological data for the presence of furbearing species, combined with the geographic area covered by each species, those which had both a relatively high frequency in the archaeological record and a large geographic distribution were chosen for inclusion. This list was then narrowed considerably by the availability of raw, unprocessed skins for each animal. Some animals which are heavily used for furs today were simply not available in the raw state, unless bought in bulk orders of hundreds of skins. Others were so rare that they are no longer hunted/trapped, or only harvested in areas outside the author's contact zone for sourcing skins.

In addition to these limitations, some very small species such as weasel (*Mustela nivalis*) were intentionally excluded from the sample collection, not because of a lack of evidence for use, but because they were too small to fit the parameters of the project, in that six samples could not be obtained from a single individual. From a comparative standpoint they are, however, an important species, and as such will be added to the collection at a later date. In the end, a number of species which would have strengthened the comparative collection were unable to be obtained, including brown bear, wolf, pine marten and wolverine.

Utilisation of Furbearers Through Time: Archaeological Evidence

While furbearers have been utilised by humans from very early on, the intensity of this use has changed through time (Charles, 1997; Rowley-Conwy, 1995b; Fairnell, 2007b). In most areas, furbearers appear to be harvested in a casual way, *i.e.* they are taken as and when they are encountered, based on their sporadic appearance and low volume in the faunal record (Charles, 1997: 274). These small numbers may represent a bonus acquired while hunting more typical game species, then brought back to camp, either for its pelt or to provide culinary variety. There are, however, a number of sites which appear to be centres where fur skin procurement was practised more intensely, at least on a seasonal basis. One of the more famous of these is the late Mesolithic site of Ringkloster, in Jutland, Denmark. Not only does this site have remains from numerous furbearers, the assemblage contains a very large number of elements from pine marten, a number which exceeds that of red deer (Rowley-Conwy, 1995: 89). The disposal of many of the pine marten skeletons still articulated, combined with the presence of cut marks associated with skinning, strongly argues for the use of this species primarily for the fur (Charles, 1997; Fairnell, 2007b; Rowley-Conwy, 1995b). In addition to the heavy use of pine marten, skulls with cut marks indicative of skinning were recovered from domestic dog, beaver, brown bear, badger and a fox (Rowley-Conwy, 1995: 96). It is not only Ringkloster at which pine marten are a favourite fur species: at the Late Atlantic sites of Agernæs and Tybrind Vig (also in Denmark) pine marten is the dominant prey species recovered with an EMNI (estimated minimum number of individuals) of 41 for Ringkloster, 34 for Agernæs and 26 for Tybrind Vig (Richter, 2005). At both sites, the marks present on the bones are consistent with skinning. Again, at both sites, the bones from other traditional furbearers such as polecat, (*Mustela putorius)*, wolf, (*Canis lupus*), fox (*Vulpes vulpes*), domestic dog (*Canis familiaris*), lynx (*Lynx lynx*), wild cat (*Felis silvestris*), otter (*Lutra lutra*) and beaver (*Castor fibre*) are present (Richter, 2005: 1224).

Though the preservation provided by the Danish bogs has recorded a more detailed look at faunal use in these areas, exploitation of furbearers is in no way restricted to these regions. Charles (1997: 256-257) notes a number of sites around Europe with evidence for the utilisation of furbearing species, including Trou de Chaleux, Trou des Nutons, Trou du Frontal, and Star Carr. The first, Trou de Chaleux in Belgium, contains the remains of three brown bear (*Ursus arctos*), with evidence of skinning, as do remains from the Mesolithic site of Medvedia Cave near Ruzin in Slovakia. The Russian sites of Avdeevo and Mezin contain nearly complete fox skeletons, with the exception of the foot bones interpreted as evidence of skinning by Klein (1973: 56) in (Charles, 1997), as does the site of Trou de Chaleux, where an MNI of 17 foxes makes the species the second most abundant at the site (Charles, 1997: 260).

Both wild cat and lynx make a frequent appearance in the faunal record as well (Crezzini *et al.*, 2014; Charles, 1997; Fairnell and Barrett, 2007a; Richter, 2005; Rowley-Conwy, 1995b). At the Mesolithic site of Galenbühel/Dos de la Forca in South Tyrol, Italy, wild cat remains are the most frequently recovered carnivore elements and show evidence of skinning as well as butchering (Crezzini *et al.*, 2014). It is not only wild felids or canids which appear in the archaeological records, as these domestic species are found with regularity, subsequent to their domestication (and in the case of domestic cats, introduction into areas outside of North Africa) (Benecke, 1987; Germonpré *et al.*, 2009; Harcourt, 1974; Losey *et al.*, 2011; Schulting, 1994; Budiansky, 1999; Fairnell, 2007b; Linseele *et al.*, 2007). While in modern society these animals are considered pets, and as such are literally off the plate, this has not always been the case. Both domestic dog and cat have in the past, and in some locations are still, utilized as a resource (Charles, 1997: 255). Fairnell's research into the use of furbearing species in the Scottish Isles shows dog elements providing the greatest number of cut marks (21 records), followed by cat with 15 records, recovered from sites spanning a time frame from the 8-9th centuries through to the 18th-19th centuries (2007: 472).

Though no data was found to indicate that similar camps centred around furbearer acquisition have been found (or at least published) in North America, the constant low-level presence of furbearing species in the faunal record, in conjunction with evidence of butchery, supports the wide ranging and continuous use of these species through time in North America as well as Europe (See Figure. 3.8-1 and Figure. 3.8-2). There is ample ethnographic evidence for the pursuit of furbearers, especially species which put on a large supply of fat for winter, such as bear, beaver, and muskrat which, in addition to having warm pelts, provide a large net caloric value which is especially important during the winter months (Helm, 1993; Nelson, 1986; Winterhalder, 1981; Yesner, 1989).

Chosen Species

While many species were used archaeologically, the species which were ultimately settled on for the comparative collection, after the mitigating factors mentioned earlier were taken into account, are:

- Domestic Dog (*Canis lupis familiaris*)
- Black Bear (*Ursus americanus*)
- Coyote (*Canis latrans*)
- Red Fox (*Vulpes vulpes*)
- Canadian Lynx (*Lynx canadensis*)
- North American Badger (*Taxidea taxus*)
- North American Beaver (*Castor Canadensis*)
- European Rabbit (*Oryctolagus cuniculus*)

All of these species have historic and/or prehistoric ranges, which more or less cover the entire geographical space outlined for this research. For fox, lynx, and beaver, this vast geographical spread, combined with a low-level continuous presence in the faunal record, and some evidence in the form of skinning marks to suggest the utilisation of their pelts, is enough to justify their inclusion in the sample collection. These three species do not appear to differ in ways which might cause significant dermal diversity between the North American and Eurasian varieties. This, combined with the less difficult nature of acquiring skins from North America, resulted in skins being sourced from the western United States and Canada. In the case of leporids, beaver, bear and domestic dog, additional lines of support were available for each species and are outlined below.

Leporids

The Lagomorpha order has perhaps been more heavily utilised than any other small game species present within the geographical confines of this research, as various species are ubiquitous and abundant throughout. It is so important within the survival strategies of certain areas that it deserves special attention. Though often thought of as large game hunters, groups of people frequenting the Late Glacial site of Robin Hood Cave at Cresswell Crags (UK), apparently valued hare quite highly. This site is a well-known example of a location where hares were a primary resource, and where a case can be made for a specialist hare trapping and processing station (Charles, 1997: 270). At the Upper Palaeolithic site of Pont d'Ambon in south-west France, rabbit and hares account for 90% of the fauna, with over 6,000 bones recovered (Boyle, 1990). The importance placed on Leporids is likely to have been cyclic, as the population of these species exhibit distinct highs and lows, often in 7 to 10-year cycles (Macdonald and Barrett, 1993). In addition to providing a caloric resource, rabbits have warm fur, and the skin of most species can be processed into a soft, wearable product. Whatever the reason for focusing on Leporids as a prey species, the importance placed on them continued through history, eventually resulting in the domestication of the European rabbit by the 1st century AD in Italy (Sykes, 2010).

Lagomorphs are not only important to Europe, ample archaeological and ethnographic examples exist for their intensive utilization in areas of North America (Codding *et al.*, 2010; Dean, 2007; Sievert, 2011; Frison, 2004; Wheat, 1967; Teague and Teiwes, 1998; Yesner, 1989). In areas such as the Great Basin and most of the desert Southwest, Leporid bones make up the majority of the faunal record, and the attendant tools used in their capture, snares and nets are also found (Byers and Broughton, 2004). In Southern Arizona, hunting Leporids accounts for over 75% of faunal remains recovered (Dean, 2007). These high percentages may not only reflect the type of prey available, but also the methods of capture. There is ethnographic documentation for drives where hundreds of rabbits were driven into long nets, where they were then dispatched with clubs (Wheat, 1967; Frison, 2004). A drive such as this is portrayed on a Mimbres bowl dating to between (1100-1150 CE) (Cannon, 2000). There are archaeological finds preserved by the exceptionally dry climate of the American Southwest of twisted rabbit fur robes, dating back to at least the Archaic period, made using the same techniques described ethnographically for groups living in the Great Basin (Wheat, 1967: 74-77).

Far to the north in the boreal forests of south western Alaska, hare played an important role as a base-line subsistence species, in the absence of numerous large game animals. Though hare are low in body fat, and in the absence of high fat plant foods (such as the pinon pine utilised in the Southwest), needed to be supplemented by anadromous fish, or higher fat mammals to prevent protein starvation, they were still an important resource that often made the difference between life and death (Yesner, 1989: 100; Winterhalder, 1981; Helm, 1993). Due to the factors outlined, above the sample collection would not be complete without the inclusion of a rabbit skin.

Beaver (*Castor sp.*)

A second species of significance in the boreal forest, as well as further to the south, is the beaver. Both the European (*C. fibre*) and the North American (*C. canadensis*) are heavily represented in the archaeological and ethnographic record (Coles and Rouillard, 2006; Helm, 1993; Irimoto, 1981; Nelson, 1986; Winterhalder, 1981; Bratlund, 1996; Charles, 1997; King, 2005; Yesner, 1989). In many boreal zones, these large semi-aquatic rodents are the second-most important species, after the primary big game animal, namely reindeer or moose (Moss and Bowers, 2007; Helm, 1993).

This species is worth noting individually, due not only to its nearly ubiquitous presence in faunal sites within its historic range, but because of its rather special part in the colonisation of North America by Europeans. The beaver is a semi-aquatic rodent and, similar to otter, has a very dense fur to insulate it from the cold waters in which it spends much of its time (Nowak, 1991: 634). When the European beaver became rare in early modern times, the pursuit of this valuable fur was a driving force behind European expansion into the interior of the North American continent (Coles, 2010: 113). This quest for fur had far-ranging effects on the subsistence economies of the native groups living in classic furbearer habitats, and ethnographies from the time emphasise the new importance placed on trapping to provide furs as a trade commodity (Winterhalder, 1981; Helm, 1993; Nicholson, 1988; Pavao-Zuckerman, 2007). The fur was so highly sought-after that the species was pushed to extinction in the British Isles, much of its historic European range, and in much of the lower 48 states of North America. The value placed on this species' fur, as well as castoreum glands, dates back to classical times, and it is no great stretch to think it was at least a locally important commodity long before (Coles, 2010: 112). Though the skin was on the moderately-difficult end of the spectrum to source, it was felt that its inclusion in the sample collection was important. Since the European beaver (*C. Fibre*) is protected in many areas, a skin from the North American variety (*C. canadensis*) was acquired out of Canada.

Domestic Dog (*Canis lupus familiaris*)

Though today's western populations seldom think of dog as a resource, aside from companionship and in some cases as providing combed fur for spinning, the faunal record emphatically proves that this was not always the case. Domestic dog remains with both skinning and butchery marks are common in archaeological sites across the geographic area covered by this research (see Figure. 3.8-1 and Figure. 3.8-2), as well as occurring in sites from at least the Mesolithic right up into the 19th century in the British Isles (Fairnell and Barrett, 2007a; Harcourt, 1974). Many archaeological finds of domestic dogs come from intentional dog burials, which occur as early as 10,600 BP in Siberia, through to early historic sites in Australia and North America (Morey, 2006: 160). Recent genetic research has placed the origins of dog domestication as early as 40,000 BP, though this has been contested (Germonpré *et al.*, 2009). Interestingly, the most divergent lineages belong to breeds from Asian, African and Arctic areas, denoting groups of dogs were present in these regions from early in their history (Wayne *et al.*, 2006). Alongside the heavy faunal representation in archaeological contexts, dog fur often shows up in ethnographic collections of Arctic clothing, and ethnographic examples of its use are common (Golovnev and Michael, 1992; King, 2005; Pitul'ko and Kasparov, 1996; Charles, 2005; Schmidt, 2009). Dogs were not only a source of meat or fur historically (and likely prehistorically) – they were also used for transporting camp goods via packs or travois in many areas, and sleds in northern regions (Morey, 2006; Nelson, 1986; Frison, 2004; Germonpré *et al.*, 2009). There are even areas where they do not seem to have been eaten (Nelson, 1986; Schulting, 1994).

In some areas, such as the American Southwest, dog fur was spun to produce beautiful finger woven belts, with complex designs worked in multiple colours, which again have been preserved by the dry climate, and can be seen on display at the Mesa Verde museum. The Northwest Coast tribes of North America had a thriving textile industry at the time of European contact and are probably best known for the colourful blankets woven from mountain goat wool and cedar bark. There are early accounts beginning in 1792 of a small domesticated breed of dog, bred solely to produce fur for weaving blankets by the Coast Salish. These accounts make frequent mention of the dogs being shorn as 'closely as sheep' (Schulting, 1994: 58). In addition to the archaeological and ethnological evidence for the utilisation of dogs, dogs are frequently portrayed in rock art as well (Gilreath and Hildebrandt, 2008; Matheny *et al.*, 1997; Schaafsma, 1986; Sundstrom, 1989). So, while the inclusion of domestic dog in the comparative collection was of obvious importance, the question of what breed remained. The Alsatian (German Shepard) was chosen to represent domestic dog in the sample collection; first and foremost, because it was available, and secondly, due to its size; which would have made it a practical dog type that one might expect to see in early contexts. It was decided, based on the literature, that breed research was likely to be unproductive, as stringent control over dog breeds appears to be a relatively recent phenomenon (Harcourt, 1974: 173).

Bear (*Ursus sp.*)

As with the other species, bear was chosen in part due to its presence in the faunal record, and its ethnographically stated importance as a fur and a winter fat source (Helm, 1993; Nelson, 1986; Berres Thomas E. *et al.*, 2004; Charles, 1997; Yesner, 1989; Rowley-Conwy, 1995b; Moss and Bowers, 2007). Bear are also frequently depicted in rock art in many areas of North America, alongside other large carnivores such as Mountain Lion (*Puma concolor*) and dogs or wolves (Matheny *et al.*, 1997; Schaafsma, 1986; Sundstrom, 1989).

In addition, two archaeologically recovered items from high profile finds have recently been identified as European Brown Bear (*Ursus arctos*). The mat of fur found at the Bronze Age Whitehorse Hill site has been identified using DNA testing as brown bear and was almost certainly once attached to the processed dermal tissue, which did not survive. This is based on the orientation and orderly appearance of the fur. Based on hair analysis, it is believed to have been a portion of skin from the back half of the animal (DNPA, 2014).

This exceptional brown bear find is not unique, and the 'Ice Man' mummy recovered from the Alps in 1991, was wearing a fur hat identified as brown bear, and shoes with brown bear fur soles, turned fur-inward and attached to deer skin uppers (Spindler, 1994). Unfortunately, a brown bear skin was unable to be sourced. Unsurprising, as in many areas brown bears are endangered, and if hunted, the furs are almost always retained by the hunter. In Europe, the brown bear is found in only a fragment of its original range, and is now restricted to Scandinavia and Russia, with a few remnant populations in the Iberian Peninsula, central Italy and south-eastern Europe (Macdonald and Barrett, 1993). Instead, the author was able to obtain a North American Black Bear (*Ursus americanus*) which is found in many archaeofaunas across North America (Figure. 3.8-1 and Figure. 3.8-2). The typical coat colours differ, but the two species do and did historically co-inhabit many environments, including the northern boreal forests, Great Plains, and much of the western United States (Berres Thomas E. *et al.*, 2004; Nelson, 1986; Nowak, 1991).

Time Period	**AD 1150 – 1500**	**9000-500 BP**	**Middle Archaic**	**5650-6889 BP**	**Middle Woodland**	**14,000-9000 BP**	**11,500 – 7,000 BP**	**1700- 1900 AD**	**3,000 – 700 BC**
Location	Alabama	Pecho Coast California	Louisiana	Florida	Georgia	Alaska	West Cent. N. America	Kansas	Wisconsin & Ohio
Site name	Moundville	combined*	combined*	Tick Island	Hartford Site	Tanana River Valley	79 sites combined*	Blue Earth Village	combined*
Reference	Jackson & Scott, 2003	Codding, 2010	Jackson & Scott, 2001	Quinn *et al.*, 2008	Carder *et al.*, 2004	Holmes, 2001	Hill, 2007	Malloy, 1993	Price, 1985
American Badger (*Taxidea taxus*)		x					x		
Black Bear (*Ursus americanus*)	x			x	x		x	x	x
American Beaver (*Castor canadensis*)	x		x	x			x	x	
Bobcat (*Lynx rufus*)	x	x		x			x		
Coyote (*Canis latrans*)	x	x	x				x		
Domestic Cat									
Domestic Dog (*Canis lupus familiaris*)	x	x	x	x			x	x	x
Fox (*Vulpes sp.*)	x	x	x				x		
Canadian Lynx (*Lynx canadensis*)							x		x
Marmot (*Marmota sp.*)							x		x
Mink (*Neovison neovison*)									
Mink	x		x						
Muskrat (*Ondatra zibethicus*)			x				x		
Mountain Lion (*Puma concolor*)	x	x						x	
Opossum (*Didelphis virginiana*)	x		x	x					
Otter (*Lontra canadensis*)				x	x	x			
Polecat									
Rabbit (*Lagomorpha sp.*)	x	x	x	x	x	x	x		
Raccoon (*Procyon lotor*)	x	x	x	x	x		x	x	
Skunk (*Mephitidae sp.*)	x	x			x		x		
Squirrel (*Sciurus spp.*)	x		x		x	x			
Weasel (*Mustela nivilis and erminea*)							x		
Wild Cat									
Wolf (*Canis lupus*)	x					x			
Wolverine (*Gulo gulo*)							x		

Figure. 3.8-1. Furbearer Presence in Selected North American Archaeological Sites.*Information consolidated from multiple sites by original author.

Time Period	14,000-10,000 BP	Late Mesolithic	Late Mesolithic	Late Mesolithic	Late Upper Palaeolithic-Mesolithic	7,900 – 7,050 BP	Mesolithic – Modern	Late Neolithic	LBK
Location	Northern Europe	Denmark	Denmark	Denmark	North Western Europe	Central Russia	Scottish Islands	Thessaly, Greece	Europe
Site name	Meiendorf & Stellmoor	Agernæs	Tybrind Vig	Rinkloster	combined*	Zamostje	combined*	Dimini	combined*
Reference	Bratlund, 1996	Richter, 2005	Richter, 2005	Rowley-Conwy, 1995	Charles, 1997	Moubarak-Nahra et al. 2014	Fairnell & Barrett, 2007	Halstead, 1992	Bickel & Whittle, 2013
European Badger (*Meles meles*)	x		x	x	x	x	x		x
Brown Bear (*Ursus actos arctos*)				x	x			x	x
European Beaver (Castor fibre)	x		x	x	x	x			x
Bobcat *L. rufus*									
Coyote									
Domestic Cat (*Felis catus*)							x		
Domestic Dog (*Canis lupus familiaris*)		x	x	x	x	x	x	x	
Red Fox (*Vulpes vulpes*)	x	x	x	x	x		x		x
European Lynx (*Lynx lynx*)	x	x		x	x				x
Marmot									
Pine Marten (*Martes martes*)		x	x	x	x	x	x		x
Mink									
Muskrat									
Mountain Lion									
Opossum									
Otter (*Lutra lutra*)		x	x	x		x			x
Polecat (*Mustela putorius*)	x	x	x		x		x		x
Rabbit (*Lagomorpha sp.*)	x				x			x	x
Raccoon									
Skunk									
Squirrel *(Sciurus spp.)*									
Weasel (Mustela nivilis and erminea)							x		
Wild cat (Felis silvestris)		x	x	x	x		x		x
Wolf (Canis lupus)	x	x			x				x
Wolverine (Gulo gulo)	x				x				

Figure. 3.8-2. Furbearer Presence in Selected Eurasian Archaeological Sites.*Information consolidated from multiple sites by original author.

3.9 Average Skin Size of Selected Species

The size of the skin provided by the species selected for the sample collection varies extensively. As the size of the skin provided by an animal could influence prey selection, it was felt that providing a rough guide for this attribute would be beneficial for this discourse. In addition to possibly affecting prey selection, the size of the piece of skin used to construct an object can be used to inform, or at least rule out, certain species. For example, a legging containing a three-foot-long, uninterrupted section of skin is unlikely to be made from a roe deer. When discussing skin as a commercial commodity, the size is generally given in square feet, and price in price per square foot. In the following table, each species has been placed into a category, each of which gives a range of square footage. (Figure. 3.9-1). This range takes into account the size variation between sexes and geographic variability seen between the same species, but only applies to adult animals.

There is a difference in terminology concerning the 'usable' square footage provided by a skin between commercial production and traditional usage. The various portions of the skin have different characteristics based on the fibre structure – for example, the belly skin has a looser weave than the back skin, and leg skin has one of the tightest fibre structures of the entire skin. Often the 'usable' portion of the skin, when discussed commercially, refers to the area remaining after the belly, leg and sometimes neck skin are removed (a double back), whereas traditional groups often use the entire skin, albeit not all for the same purpose. In light of this research's prehistoric focus, the range of square footage given is in reference to the entire skin. The approximations given are based solely on the author's personal experience.

Species	Square Footage	Species	Square Footage	Species	Square Footage
American Badger *Taxidea taxus*	**XS**	Fallow Deer *Dama dama*	**M-L**	Red Fox *Vulpes vulpes*	**XS**
Beaver *Castor Canadensis*	**S**	Galloway Cow *Bos taurus*	**XXL**	Reindeer/Caribou *Rangifer tarandus*	**L**
American Bison *Bison bison*	**XXL**	Domestic Dog *Canis lupus familiaris*	**XS-M**	Roe Deer *Capreolus capreolus*	**S**
Big Horn Sheep *Ovis Canadensis*	**M**	Moose *Alces alces*	**XL**	Soay Sheep *Ovis aries*	**S**
Black Bear *Ursus americanus*	**M**	Mule Deer *Odocoileus virginianus*	**M**	Toggenburg Goat *Capra aegagrus hircus*	**S-M**
Canadian Lynx *Lynx canadensis*	**S**	Pronghorn Antelope *Antilocapra americana*	**M**	Wild Boar *Sus scrofa*	**S-M**
American Elk *Cervus Canadensis*	**L-XL**	Rabbit *Sylvilagus sp*	**XS**	Red Fox *Vulpes vulpes*	**XS**
Exmoor Pony *Equus ferus caballus*	**L**	Red Deer *Cervus elaphus*	**L**	Reindeer/Caribou *Rangifer tarandus*	**L**

Figure. 3.9-1. Approximate Square Footage of Skin for Sample Species. Extra Small (**XS**) = under 5 sq. ft. | Small (**S**) = 5-10 sq. ft. | Medium (**M**) = 10-15 sq. ft. | Large (**L**) = 15-20 sq. ft. | Extra Large (**XL**) = 20-30 sq. ft. | Extra-Extra Large (**XXL**) = over 30 sq. ft.

Chapter 4

Methodology for Chosen Tanning Technologies

4.1 Introduction to Methodology and Skin Morphology

The rational for the tanning technologies and species chosen has been covered in the previous chapters. There are many possible variations in processing hides individually, but most of these variations still have a common sequence of tasks. Thus, the phases within hide processing can be used as a means of grouping sets of actions together. Rather than using many individual variations as part of the experiment, tasks were instead grouped into common phased sequences, so that some variables could be better controlled. The design of the programme of experiments needed to be kept constant. What follows is a discussion of the specific tanning methods and their sequences. In some processes compromises were reached in the use of standard modern tools, or standard modern compounds, so that variation was controlled as much as possible. Steps in each process, such as time in solutions were monitored and recorded, and data which might explain variations such as age, sex, and season of harvest were, where possible, noted for each species acquired. In an effort to decrease variation caused by some of these factors the samples were all taken from a single individual animal for each species. All samples were taken from the same area of the skin, a rectangular section which runs from behind the shoulder to the flanks and from the spine to the top edge of where the belly skin begins.

Practical considerations in handling the number of samples produced and the storage requirements were also factored into the choices made. For all these reasons, tanning methodology comprises its own chapter to make clear the methodological rationale behind the practical work. What follows is organised by sequence and tannage type, with the reductive processes undergone by all samples covered initially, then followed by the procedure specific to each tannage type. A discussion of some notable species-specific characteristics and interesting observations on the tannage technology follows.

Understanding the nature of skin is important to understanding the tanning process, and in communicating information about this process. The skin is a complex organ, the detailed description of which is unnecessary for this discourse, and which has been thoroughly covered by other authors (Haines, 1991a; Reed, 1972; Reed, 1966; Covington, 2011).

However, the terminology applied to the various portions of the skin which are dealt with during the tanning process vary by practitioner, and merit clarification. The three basic layers of skin are the epidermis, dermis and hypodermis. The dermis is divided into two portions, the upper grain (or papillary) layer, and the lower mid-dermis (or corium) layer, which are separated by the mid-dermal or grain-corium junction. The hypodermis (subcutaneous fat, muscle and membrane) are removed for all tannage types. The epidermis is removed for all hair-off tannage types, and the grain is removed for many fat tannages. While this broad overview of skin morphology by no means covers its complexity, it has been included to clarify terminology and improve the readability of the following sections Figure. 4.1-1.

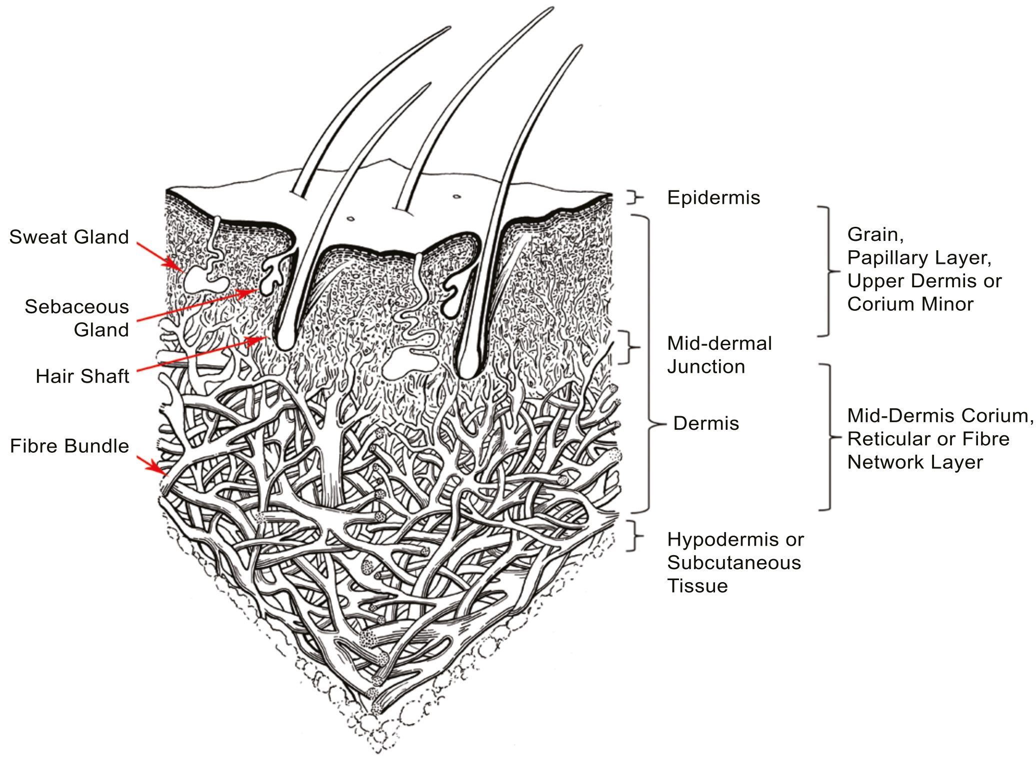


Figure 4.1-1. Vertical cross section of skin showing the major features. Source: Author (Based on Hurcombe, 2014). Original drawing: Seán Goddard.

4.2 Reductive Treatments

As referenced in chapter two, there are a number of general reductive treatments applied to a skin, prior to the more specific additive treatments which characterize each tannage technology. The reductive treatments used for the sample collection were standardised to increase comparability between technologies and species.

De-fleshing

De-fleshing was done using a metal scraping tool (Figure. 4.2-1) over a plastic tanner's beam (Figure. 4.2-2). This method was chosen due to the small size of some of the samples that could be acquired for each species as well as time constraints. These limitations precluded de-fleshing the samples in frames, as using this method means a small portion of the skin outside the lacing is wasted. In addition, lacing a skin into a frame is time consuming and the surface produced in the de-fleshing process differs little between the two methods if the skin is de-fleshed while wet. In light of these considerations de-fleshing wet hides over a beam was selected as the preferred method of flesh and membrane removal. Figure. 4.2-3, and 4.3-4 show variations of the de-fleshing process.

Justification for the use of non-period appropriate tools in processing the samples is as follows. The research aims of this project focus solely on the finished product of each tannage technology, not the tools used to produce it. The time necessary to construct and maintain the number and quality of bone and stone tools necessary to de-flesh, de-hair, de-grain and soften over 150 samples was prohibitive. While using stone and bone tools would have produced an interesting and rather extensive tool collection for use wear analysis, it was felt that, in terms of time and labour, this extra task was not feasible and that metal tools were the sensible compromise. In the author's experience the surface produced by using metal on wet skins differs very little from using bone in the same way. There will be, however, differences in surface texture apparent between dry hide that has been scraped using stone tools and hide in the same condition which has been scraped with metal tools. As a result of retouching, stone tools have serrated edges. These serrations can be made very fine but cannot be eliminated entirely. The serrations carve fine grooves into the skin surface being scraped. These grooves are not produced by the smoother edge of a metal tool. Based on observations of archaeological pieces during fieldwork this difference in surface texture appears to survive in some archaeological leather.

De-hairing and de-graining

The choice to remove the fur or hair from some species, but not from others is based on the most common general use of the skin of each species. For example, rabbit pelts are most commonly used as a fur. Without the fur, a rabbit skin is a

Figure 4.2-1. Wet scraping tool.

Figure. 4.2-2. Plastic tanner's beam, which can be used as a 'Pull' or 'Push' beam.

very small, very thin piece of processed skin which would be of limited use. A moose skin, however, is most commonly used with the hair removed, as the hair is brittle and breaks off easily. Some species such as reindeer are commonly processed as both a hair-on and hair-off product.

Other standardised steps undertaken for all samples included washing the freshly de-fleshed skins in clean tap water, which was warm but not hot to the touch. Samples designated for dry scrape fat tannage, and samples where the fur or hair was to be left on were not placed in an alkaline bath. All other samples were placed in an alkaline solution of potassium hydroxide (KOH) to slip or loosen the hair. Potassium hydroxide is the alkaline component in wood ash, a material well documented ethnographically as a de-hairing and degreasing agent. This is the most likely source of alkaline solutions used for similar purposes prior to the production and use of slaked lime (Cameron, 1998; Thomson, 1991a; 1981; Richards, 1997). The chemical in its pure form was used to provide consistent solution strength, again with the aim of comparability between sets of samples in mind. The KOH was purchased from Fisher chemical supply and was assayed at 86.8% purity. 156.3 grams (5.5 ounces) of KOH were added to approximately 60 litres of water. At this concentration the solution registered 12-13 pH on the first day of immersing the sample skins, 12-13 on the second day, and 12 on the third day. Very few skins required longer soaking times than this, but the pH never dropped below 12 during any of the longer soaks. For comparison a solution leached from wood ashes also measured 12-13 on the pH scale. Reiteration of the basic skin processing concept 'anything that will damage living skin will also damage the skin being processed' is worth mentioning at this point. This solution strength is not dangerous and will do no more damage to living skin than cause dryness. It will, however, irritate eyes and bleach clothing, caution in handling was taken.

The samples were left in the solution until the hair could be pulled out with little effort. This stage was reached in various amounts of time depending roughly on the thickness of the skin and the coarseness of the hair. Thinner skins or finer haired species slipped (fell out) more quickly, often overnight, while thicker skins or species with coarser hair took up to 5 days for the follicles to loosen enough for hair removal. With the exception of samples destined for fat tannage (which involved the removal of the grain surface), when the hair loosened sufficiently each skin was placed back over the tanning beam and the hair carefully pushed off using a rectangular wooden tool with a rounded edge. Great care must be taken not to damage the grain surface during this stage. To avoid damage to the grain from the beam edge, towels were placed under and over the skin where it draped over the beam and was caught between the beam and the wall. Using a push beam shown in Figure. 4.2-3, which traps the skin between the beam edge and the tanner's waist would also mitigate this type of damage. Samples which were to be fat tanned had the grain removed during the de-hairing step so, for the fat tanned samples, this caution was unnecessary. A side effect of the alkaline solution is swelling of the skin. This effect can be advantageous in removing the grain layer using the wet scraping method

Figure 4.2-3a and 3b. Two variations for using a push beam for wet scraping.

and is discussed in section 4.2. For other tanning methods and for thicker skins it can be detrimental. The swollen skin can be difficult to manipulate on the tanning beam and makes the grain surface more susceptible to damage. This effect can be controlled to some degree by adding a small amount of salt to the solution, but this also slows the speed at which the hair is loosened. No salt was added during this process, as samples destined for all six tannage types were soaked in the alkaline bath together. Another side effect of the alkaline solution is the more efficient and thorough removal of the ground substance from between the dermal fibres. As mentioned in chapter 2, the ground substance is made up of soluble interfibrillary proteins and mucous. Most of which must be removed in all skin processing technologies, with the exception of rawhide. In living skin this chemically complex substance determines the amount of water held within the dermal network. It appears to do this by controlling the 'passage of aqueous fluids containing charged ions through the skin' (Reed, 1972: 31). The removal of a portion of the ground substance, creates space within the dermal network, which allows aqueous solutions to penetrate more effectively (Reed, 1972; Cameron, 1998; Covington, 2011). Secondarily, the alkaline solution helps to degrease the hide by creating a saponification reaction which degrades any triglyceride grease present within the fibre structure (Covington, 2011: 139)

All de-haired samples were next neutralized, with the exception of those intended for wet scrape fat tannage. For the wet scrape method, the swollen grain is advantageous during the de-graining process, and, though they can be effectively de-grained in an unswollen state these samples were processed in the swollen state. For the other samples the pH level must be returned to neutral to facilitate the uptake of tanning agents during the following steps. Neutralizing can be achieved, albeit slowly, by soaking the alkaline skins in successive tubs of fresh water until the rubbery, swollen feeling of the skin is lost. It can also be achieved by placing a skin in a pond or running stream and allowing the alkalinity to leach out. No river or pond was available for this project and as a time saving measure a mild neutralizing solution was used to lower the pH level of the samples. This solution consisted of 240 ml (1 cup) of vinegar to 8 litres (2 gallons) of water with an approximate pH of 4. Sample skins were allowed to soak in this solution until they were no longer swollen, and the rubbery feeling was lost. When neutral the skin will feel slippery not rubbery and will hold a stretch when pulled in one direction. This stage was reached after only 10-15 minutes for most skins, with the exception of the very thick skins of bison, wild boar and domestic cow. Finally, all samples were soaked for 1-2 hours in clean, plain, tap water to ensure they were not to acidic.

A slightly different reduction sequence was applied to samples where the hair or fur was to remain in place. All samples were de-fleshed and washed as explained above. Following de-fleshing, the samples were placed in a pickling solution to tighten the hair follicles and mitigate any unintended loss of the hair or fur (slippage). Both the acidity and the salt of the pickle prevent bacterial growth, which causes the hair to slip. I stress that this step is not necessary for tanning furs and would not have been necessary prehistorically, given that a tanner could flesh and cure (salt, dry, or freeze) the skin immediately. The majority of the fur samples for this project were tanned over a week-long period in July, as part of a public demonstration for St. Fagan's National History Museum in Wales. Due to the ambient summer temperatures, large number of samples being tanned, and the lack of cool storage areas available, the choice to use a pickle was made as a precaution. The hair and fur on skins were soaked for approximately 1 hour in a solution of 350 ml (1.5 cups) of 6% vinegar and 240 ml (1 cup) of salt in 8 litres of water. This solution had a pH level of 2-3. The furs were rinsed briefly to raise the pH slightly and remove any excess salt from the fur before undergoing the remaining steps for the various tannage technologies.

4.3 Fat and Smoke Tannages

As mentioned in chapter one, this combination of tannage technologies is very ancient. Fat tan and smoking are so interconnected that they are often talked about as a single technology. They are, however, two separate technologies with differing properties and chemical components.

During fat tannage lipids are introduced to spaces in the dermal network left after removing the majority of the ground substance. These lipids, depending on the saturation level of the lipid added and the warmth produced during the softening process, oxidise to various degrees. This oxidation produces aldehydic compounds which create a polymer matrix which mirrors that of the collagen matrix, thereby supporting the collagen fibre structure, and preventing its collapse and the re-sticking of the fibres which would accompany this collapse (Covington, 2011: 317). Only lipids with medium to high levels of unsaturation are capable of oxidising at temperatures below the general shrinkage temperatures of the raw collagen from which the skin is composed. In the commercial production of chamois, cod oil is used, and the heat is blown in – in the form of hot humid air to create a temperature of 40-50 °C (which initiates auto-oxidation (Covington, 2011: 316).

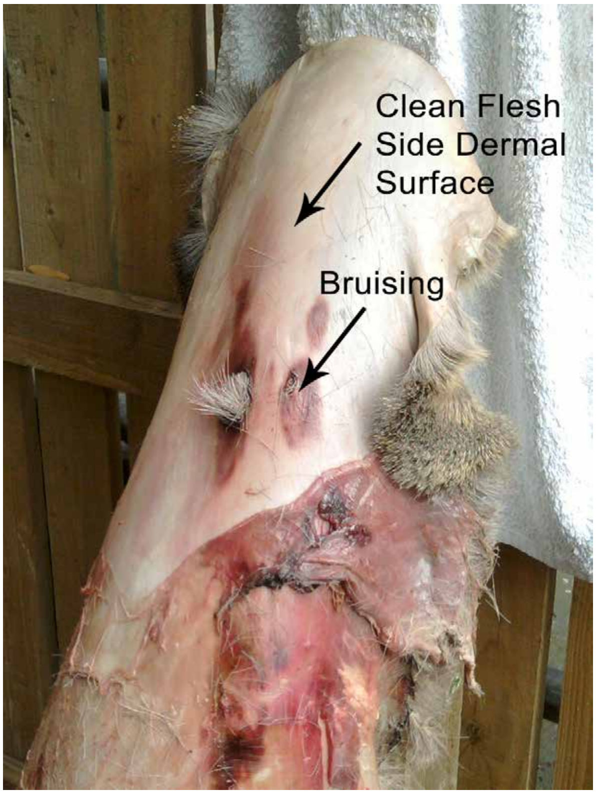
In the case of traditional fat tannages, the use of warm dressing solutions and the friction created during the aggressive softening process produce a similar, though not as consistent effect. In the case of brain tannages, the brains themselves contain a large percentage of unsaturated fats similar to egg yolks (Bitman, 1976). In addition to having an advantageous composition of fatty acids, brain tissue contains components which help to deliver these into the dermal structure. Brains are high in phospholipids, notably lecithin, which acts as a powerful emulsifier for the fatty acids contained in the brains, as well as fat from any other source added to the mixture (Haines, 1991c: 24). This emulsification action helps to suspend the fat particles in an aqueous solution, which acts as the delivery system for transporting the lipids through the full dermal thickness. Analysis of brain tanned leather show 20-25% of the bonded lipid content remains after washing and is not solvent extractable (Haines, 1991c: 25).

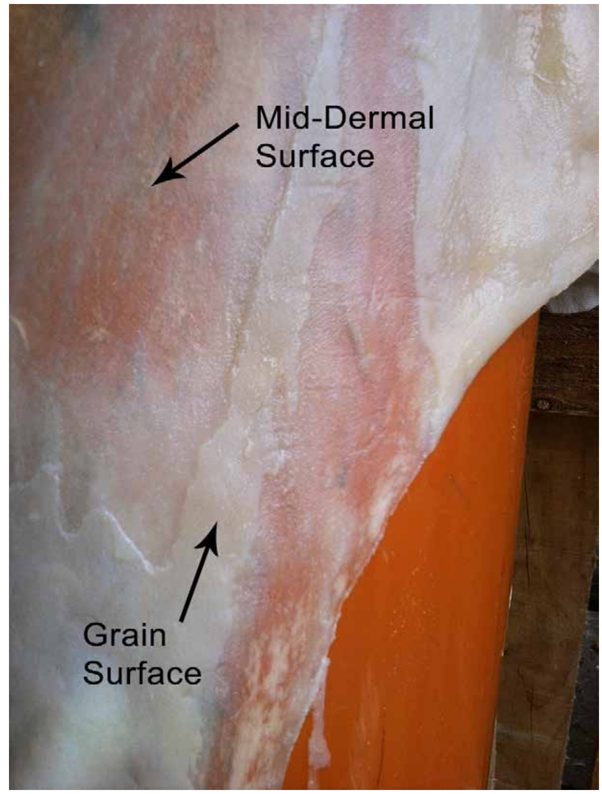
Smoke, as a stand-alone tannage type relies on the aldehydic compound acrolein which is a by-product of burning wood (Covington, 2011: 333). This compound reacts with the charged primary amino groups of the collagen alongside phenols, a second compound found in wood smoke which appears to react with other sites via hydrogen bonding (Haines, 1991c: 25). These reactions remove some of the hydrophilic properties of the collagen helping to prevent the re-sticking of the dermal fibres on drying. When used in combination with fat tannage, the heat from warm smoke further oxidises the lipids creating more aldehydic compounds and oil polymers, further cementing the tanning action (Haines, 1991a; Reed, 1972).

The overwhelming use of this type of combination tan over a wide geographic area, including all of North America, many parts of Scandinavia and Siberia as well as numerous areas outside the parameters of this research, has been documented ethnographically (Mason, 1891; Oakes and Riewe, 1995; Issenman, 2011; Klokkernes and Kunstakademi, 2007; Binford, 1967; Beyries, 2008; 2002). In light of this, all of the fat tanned skin samples have also been smoked, though a small sample of each was removed prior to the smoking process for later chemical analysis and comparison, as not all groups who use fat tannages smoke the resulting skins.

The soft handle associated with this tannage type is achieved using aggressive manual manipulation of the fibre structure during the drying process. This manipulation can be achieved in many ways, including softening in a frame, pulling the hide soft by hand, and many variations of stretching the skin using the mechanical advantage offered by objects such as staking posts, and cables. (Figure. 4.3-10)

Similar to the variety of softening techniques recorded, there are many variations on the reduction techniques employed to prepare the skin for the addition of lipids. The varieties, however, roughly fall into two categories; wet scrape and dry scrape. These are differentiated by the water content retained by the skin during the de-fleshing, de-hairing, and possible de-graining of the skin prior to the oiling (fat liquoring) and softening stages. De-graining is stated as optional as it is not done ubiquitously either geographically or temporally. As a broad generality the grain is removed in North America but not as consistently





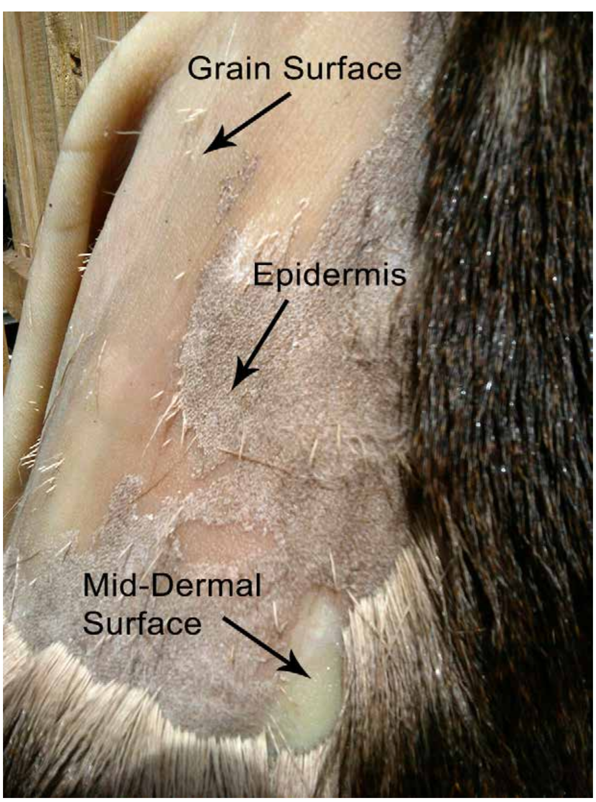


Figure. 4.3-1. A- De-fleshing, wet scrape method, B- De-hairing, wet scrape method, C- Grain removal wet scrape method. The raised surface is the grain.

in Europe (Rahme, 1996; Richards, 1997; Young et al., 1991; Kamper, 2016; Mason, 1891; Walsh, 1964).

When leaving the grain on, this outer surface benefits from the application of a more robust lubricant such as lard, (rendered adipose tissue) or heavy oils such as bear fat, neatsfoot oil or any number of vegetable oils to reduce cracking of the grain surface during the energetic softening process. In very early periods few vegetable oils would have been available in the quantity needed to serve as a skin dressing, however, as mentioned in chapter 2, sesame oil was used to treat skins in ancient Egypt and Mesopotamia, and it has been suggested that gold-of-pleasure (*Camelina sativa*) could have been employed for this purpose in prehistoric Europe (van Driel-Murray, 2002: 254; 2000: 303). Further experimentation is needed to clarify the use of these oils.

The various animal fats must be rendered in order to keep them from going rancid. Rendering involves heating fat or fatty tissues either in boiling water or in a dry container and skimming the resulting grease off the water's surface or pouring it away from the fried tissue. This grease can be further clarified by pouring it through sieves to clean out unwanted solids and reheating, which allows the solids to settle to the bottom as the fat liquefies. If not removed these solids, made up of mostly proteins, cause the onset of more rapid rancidity. Most body fats upon cooling will be solid at room temperature. However, many marine animal fats, bear fat, mink oil and neatsfoot oil are liquid at room temperature. Neatsfoot oil is rendered from the foreleg and foot bones of ungulates and is composed mainly of olein with some palmitin and stearin. The small amount of palmitin and stearin harden when the oil is cooled, while the olein stays liquid and are easily separated off during processing (van Driel Murray, 2000: 301; Landman, 1991: 30). These fats allow for better functionality of the poorly insulated lower limbs in cold conditions. The more liquid nature of these oils at room temperature allows them to soak in more quickly with more even distribution when used as a dressing for the grain surface, than do the more solid saturated fats. The presence of large accumulations of forelimbs at many tannery sites as early as the 1st or 2nd century AD, may indicate that production of this oil has a reasonable level of antiquity (Thomson, 2009: 2).

For fat tans at this stage of sample preparation, a grain off method was chosen. Other tannage technologies employed for this research retain the grain, providing samples which show the grain pattern for speciation purposes. As time allows fat tanned grain-on samples of each species will be added.

Wet Scrape Method

All samples were de-fleshed over a tanner's beam, washed, and then the hair-off samples placed in an alkaline solution as described in the reduction treatments section above. When the skins had reached the stage where the hair had loosened, the samples were removed from the alkaline solution then de-haired and de-grained simultaneously, using the same tool used for de-fleshing. De-graining consists of separating the epidermis and grain layer, sometimes referred to as the papillary layer, from the dermis or fibre layer at the mid-dermal junction (Figure. 4.3-1). The dermis is often referred to as the corium. While in thicker hides, such as cow or horse the grain layer is difficult to remove without a sharp tool; in thin to medium thickness skins a tool with a distinct but not sharp edge is ideal. After being in the alkaline solution the grain is easy to remove, not because of a chemical change, but because the swollen tissue is easier for the scraping tool to bite against. It is also less difficult, to distinguish the grain layer from the underlying dermis in this state, as well as notice any small areas which have been overlooked. Areas where the grain has been missed, will be stiffer than the rest of the skin after softening and slightly scratchy in texture.

Not all fat tans have the grain layer removed. Many arctic communities do not remove the grain before tanning sea mammal skins (Oakes and Riewe, 1995; Wilder, 1976; Issenman, 2011). The Saami regularly produce grain-on fat tanned reindeer skins (Rahme, 1996; Klokkernes and

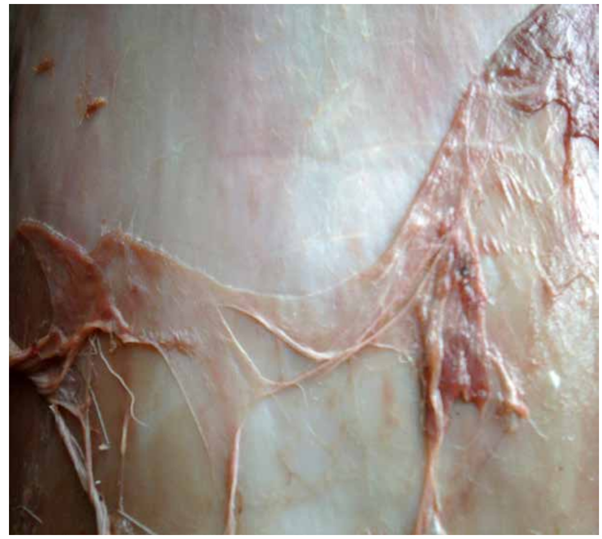


Figure 4.3-2. Membrane Removal wet scrape method.

Kunstakademi, 2007) and some artefacts observed during field work in both Europe and North America were grain-on and likely fat tanned. The rationale for removing the grain when fat tanning is two-fold, primarily, it is a decision based on the compact nature of the grain layer posing a physical barrier to the adequate distribution of emulsified fats through the dermal thickness. Secondarily, cracking of this layer can be caused by the reaction of the aldehydic compounds produced by the oxidation of the fatty acids reacting with the remaining keratin in the grain layer (Haines, 1991c: 25). The grain portion of the skin has a much higher percentage of keratin than the rest of the dermis, with the highest concentrations being found in the epidermis (Covington, 2011: 118). Hence the aldehydic compounds do not negatively react with the dermis, the majority of which is made up of collagenous proteins.

After the grain was fully removed, the hair-off samples were neutralized and rinsed as outlined in section 4.1. If necessary, a further step on the flesh side, referred to as de-membraning (or membraning), was employed. The subcutaneous connective tissues which lie under the muscle layer are not always fully removed during the de-fleshing process and it is more efficient to do this step after the hair is removed (Figure. 4.3-2). With the padding provided by the hair removed the skin can be better trapped between the scraper and the beam, allowing the tool to 'bite' against the membrane more effectively and pull or push it off. The motion and tool used are the same as for the de-fleshing process. All samples intended to be hair-on were brained and worked soft immediately after fleshing or were frozen for a later date.

Having completed the reductive treatments, the next step involved the addition of light weight hydrosoluble lipids found in brain tissue in the form of an aqueous

Figure. 4.3-3a and 3b. Brain solution and brained sample at the stage where they begin to turn white, as moisture is lost from the sample and the fibres are worked open.

Figure. 4.3-4a, 4b and 4c. A: Tools used for de-fleshing in a frame, B: De-fleshing in a frame using a toothed bone tool, C: show close up of a toothed bone scraping tool.

solution (Figure. 4.3-3). One brain from a medium sized roe or fallow deer was used for approximately 7 samples, with samples ranging in size from 10 x 15 cm (4 x 6 inches) to 20 x 30 cm (8 x 12 inches) depending on species. The brain was placed in 1-1.5 litres (1.06-1.6 quarts) of water and boiled until the tissue turned from pink to white. Care was taken to remove any bone fragments which can be quite sharp. The tissue was then thoroughly pulverised by mashing it between the palms and whisking it with a fork to release as much oil as possible into solution. Any bits of stringy membrane were removed and disposed of. The solution was reheated to boiling to facilitate any further release of oil then allowed to cool enough to touch comfortably.

While the brain solution cooled, the skin samples were rolled into dry towels and trodden upon to remove excess moisture from the fibres. When the solution had adequately cooled, the now tacky feeling samples were placed into it and manually manipulated to augment the absorption of the lipids by the dermal fibres. The solution temperature is cool enough to use safely when it no longer burns the skin on your hands. Each sample was wrung out by hand then hung to partially dry. When the samples began to feel tacky they were briefly stretched by hand until the separation of the fibres changes the skins colour to white then placed back in the solution (Figure. 4.3-3a). This process was repeated 3 times for each sample before final softening was begun. Each round of this is defined as '1 braining'. Many of the thinner skins only required this first round of oil impregnation. Thicker skins or those with a more tightly woven fibre structure required multiple braining before full softening was achieved. In this case, fully softened is defined as the lack of any sort of crunchy

Figure 4.3-5. Close up of dry scrape tool, blade shape and edge angle.

or papery handle, and the ability to stretch in all directions. This stretch is more apparent in thinner skins. With the thickest skins, including cow and bison, full softness was achieved when the skin could be folded in half and the fold rolled along the length, width and diagonal of the sample. Softening was achieved by consistent manipulation of the fibre structure in all directions until the dermis lost all moisture. This was accomplished by pulling the samples in all directions and rubbing them using a back and forth motion between the hands, as well as pulling them through a cable and over a staking post (Figure. 4.3-10). In an effort to reduce drying times, which were often impeded by less than advantageous British weather, samples were often placed in the warm dry airing cupboard for 15 to 20 minutes between manipulation cycles. If, after fully dry, a skin did not meet the fully softened criteria, it was returned to the oil solution for another 'braining'. The number of brainings required for each species was recorded and is summarised in Figure. 4.3-9 at the end of the dry scrape section.

Dry Scrape Method

All species and samples were de-fleshed over a beam using the metal wet scraping tool, as described in the reduction treatments section above. No alkaline solution was used for dry scrape samples. They were instead laced into a frame immediately after de-fleshing was complete. Skins can be fleshed in a frame as well and, when done this way, a serrated bone tool is very efficient at cleaning away the flesh and membrane (Figure. 4.3-4). After being laced into the frame the de-fleshed, hair-off samples were stacked in the airing cupboard and allowed to dry completely, before proceeding onto de-hairing and de-graining. All samples with the hair remaining in place were brained and worked soft immediately after framing or, were dried to be softened at a later date. Unlike wet scrape, which pinches the skin between the tanning beam and the scraping tool, then pulls or pushes the grain and hair-off, dry scrape requires a sharp tool which shaves off the hair, epidermis and grain layers. The tool chosen for this task is based on the angled scraper used extensively on the Great Plains for processing bison hides (Richards, 1997, Kehoe, 2005), (Figure. 4.3-5).

When the skin is fully dry it will be very taut, similar to a drum head and care must be taken not to cut or scrape holes in the thinner areas such as the axilla (armpits). The tool is used by dragging it down the skin, using a motion that is 90 degrees to the cutting edge (Figure. 4.3-6). Slipping sideways with the tool will score or cut holes into the surface. When dry, the grain appears as a slightly different colour and texture to the dermal surface underneath. The colour contrast varies by species, with some species having a darkly pigmented grain layer. Even when no colour contrast exists, there is always a textural difference which allows the tanner to judge when all of the grain has been removed (Figure. 4.3-7). If necessary, the flesh side was also given a light scraping to remove any membrane remnants.

The aqueous solution of hydrosoluble oils was prepared in the same way as outlined for the wet scrape method. Instead of soaking the samples in the solution, however, it was rubbed on using a cloth rag. This pushes

Figure 4.3-6. De-hairing and De-graining, in a frame (dry scrape method).

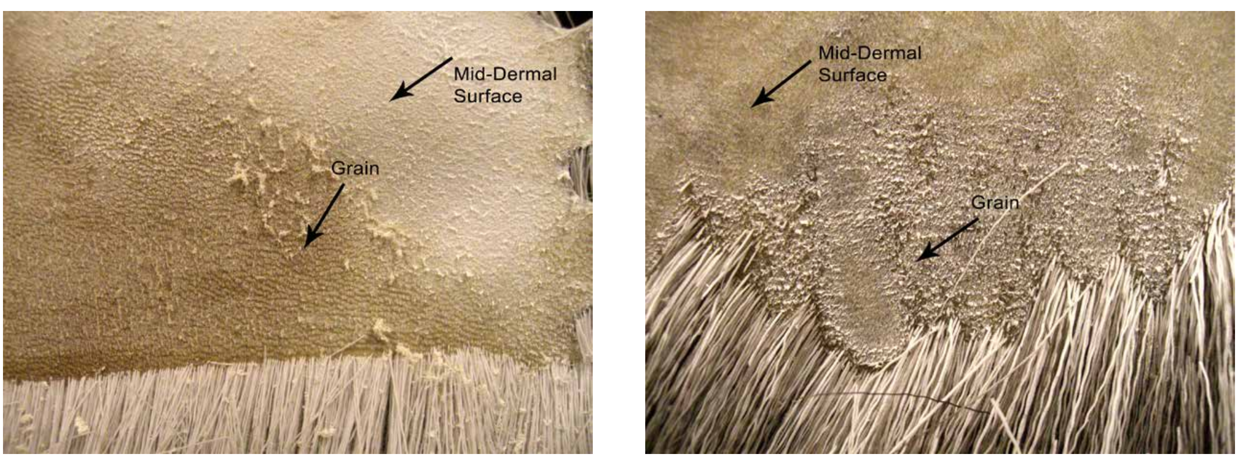


Figure 4.3-7a and 7b. Close up showing grain removal on a dry skin A- Mule Deer, B- Moose.

the water and oils into the skin fibres. It also works nicely on furs, as it keeps any excess oil and any accompanying solids, out of the fur, making for a cleaner final product. Also, as the fur stays dry using this method, the skin can be worked soft more quickly. When wetted the fur can take a very long time to dry completely and, as the skin cannot be left without manipulation of the fibres for long, wet fur can substantially increase the length of time necessary for the softening process.

The solution was rubbed and worked into the skin as it began to dampen and soak up the solution. A thin coat was wiped on then allowed to absorb as the skin rehydrated. This was repeated until the skin was fully 'damped back'. Full rehydration was evident when the skin reverted to a grey blue colour, and even flexibility returned to the fibres. At this point the skin fibres were manipulated using a lightly serrated bone tool. This tool was originally made as a de-fleshing tool for removing the flesh and membrane from framed skins, but after smoothing the serrations slightly, it served admirably as a softening tool. The fibres of the skin were worked by pushing the tool into the skin and dragging it in various directions to stretch and move the fibre network as it dried (Figure. 4.3-8). If the skin did not work soft after the first application of brain solution it was re-brained and worked again in the same way. After the skin was fully dry and soft it was cut out of the frame just to the inside of the lacing holes,

Figure 4.3-8a and 8b. Softening in a frame. Close up of fibres stretching and bone tool use.

Species	Brain Tan (Dry Scrape)	Brain Tan (Wet Scrape)	Species	Brain Tan (Dry Scrape)	Brain Tan (Wet Scrape)
American Badger *Taxidea taxus*	2	1	Mule Deer *Odocoileus virginianus*	2	2
Beaver *Castor Canadensis*	2	1	Pronghorn Antelope *Antilocapra americana*	2	2
American Bison *Bison bison* Hair On	3	3	Rabbit *Sylvilagus sp*	3	2
American Bison *Bison bison* Hair Off	2	3	Red Deer *Cervus elaphus*	2	3
Big Horn Sheep *Ovis Canadensis*	1	1	Red Fox *Vulpes vulpes*	1	1
Black Bear *Ursus americanus*	3	3	Reindeer/Caribou Rangifer tarandus Hair on	1	2
Canadian Lynx *Lynx canadensis*	NA	1	Reindeer/Caribou Rangifer tarandus Hair off	2	2
Elk *Cervus Canadensis*	3	3	Roe Deer *Capreolus capreolus*	2	2
Exmoor Pony *Equus ferus caballus*	4	3	Soay Sheep *Ovis aries* Hair off	3	2
Fallow Deer *Dama dama*	1	1	Soay Sheep *Ovis aries* Hair on	2	1
Galloway Cow *Bos taurus*	4	3	Toggenburg Goat *Capra aegagrus hircus* Hair on	2	NA
German Shepard *Canis lupus familiaris*	2	1	Toggenburg Goat *Capra aegagrus hircus* Hair off	2	2
Moose *Alces alces*	3	3	Wild Boar *Sus scrofa*	5	NA

Figure 4.3-9. Number of Brainings Per Sample.

leaving a thin strip of the outer edge behind. This outer edge does not soften during the working process and is a waste product of this technique. It can, however, be cut into thong/lace and used, for example, when lacing future skins into a frame.

Smoking or Smoke Tanning

The fat tanned samples, though now very soft, are more versatile after they are smoked. White fat tan will return to a stiffer state if the skin is wetted and allowed to dry without being worked soft again. Though, a secondary

Figure 4.3-10a, 10b and 10c. A- Softening skins using a staking post, and B- rubbing between the hands. C- A metal cable for pulling the skins through is shown on the right.

softening is never as laborious a process as it was initially. If exposed to wood smoke, however, the fat tan changes dramatically and will stand up to wetting and even washing without becoming stiff, as long as no harsh detergent is used. Smoking can be done in a number of ways, including using a smoke house, hanging it in the rafters of a shelter or sewing it into a bag which is placed over a stove pipe or hole in the ground to funnel the smoke into the skin bag (Figure. 4.3-11a and 11b). For this project a smoke house was constructed, using a frame of 1 x 2-inch (2.5 x 5 cm) dimensional scrap lumber covered with old bed sheets and towels to contain the smoke (Figure. 4.3-12). The samples were hung in rows within the smoke house, and warm smoke was directed into it, from a pit in the ground where a small fire was lit in a ceramic pot. The fire was kept mostly smothered with punky (half rotten) wood. This creates a large amount of smoke with only low heat. If the temperature

Figure 4.3-11a and 11b. Smoking a full skin by sewing it into a bag and suspending it over a stove pipe (A) or a fire pit (B). The cloth is cotton skirting to protect the skin from the heat and funnel the smoke into the skin bag.

Figure 4.3-12a, 12b, 12c and 12d. A, B, C- Smoking samples by hanging them in a makeshift smoke house made from scrap lumber and old towels. D- Shows the smoky fire inside the clay pot.

gets too high, it will damage fat tanned skins severely. The samples were smoked for 9.5 hours from 1:30 pm till 11:00 pm. It does not matter if the smoke is warm or cool, as long as the skin is exposed to it for a long enough period of time. However, warm smoke appears to impart colour to the skin more quickly. When using the skin bag method, the first side is finished when the colour imparted by the smoke begins to bleed through the thin areas of the skin. It is then turned inside out, and the other side smoked for an equal amount of time. In a smoke house the skins are smoked until an even colour is achieved. Using the skin bag with warm smoke is the fastest method, and the warmth helps to further oxidise remaining lipids within the skin. Whilst colour is often used as a gauging characteristic for how well the smoke has penetrated the skin, the actual chemical action of the smoke happens more quickly in the author's experience, than the appearance of the colour. As little as 20 minutes using the bag method is sufficient to significantly improve the fat tans rewetting properties. The colour is mostly imparted by tars carried in the wood smoke and as such has little to do with the actual chemical changes.

4.4 Vegetable Tannage (Bark Tannage)

The samples from all species were de-fleshed over a beam, washed, and then the hair-off samples placed in an alkaline solution as described in the reduction treatments section. When the hair had loosened, the samples were removed from the alkaline solution and de-haired using a wooden tool with a blunt edge to push off the hair without damaging the grain surface. All samples intended to be hair-on were put into the tannin solution directly after fleshing or were frozen to be added as a batch at a later date. After de-hairing, the hair-off samples were neutralized and rinsed.

At this stage both hair-on and hair-off samples were suspended in a tannin solution. The solution was made by extracting tannins from oak bark (*Quercus sp*.). The oak bark was crushed using an oversized wooden mortar and pestle after being thoroughly dried in the airing cupboard. It was broken down into as small of pieces as possible in a 3-hour time period. The largest pieces were approximately 3 inches long and 1.5 inches wide (7.6 x 5 cm) (Figure. 4.4-1). Each batch of bark was boiled in fresh water three times. These multiple boiling cycles produced solutions with decreasing concentrations of tannins.

Tannins comprise a large group of plant polyphenols and are secondary metabolites of higher plants, which have the ability to react with collagen (Khanbabaee and van Ree, 2001). The reaction of these polyphenols with protein is the cause of the dry mouth sensation experienced when biting into a green apple and is referred to as 'astringency' (Covington, 2011: 281). This reaction with protein, is the basic reaction behind tanning using polyphenols or tannins. The tannins can be divided into two groups, the condensed (catechol) and hydrolysable (pyrogallol) tannins (Reed, 1972). The hydrolysable tannins can be further divided into ellagitannins and gallotannins, both of which, as the name suggests, are soluble in water. Ellagitannin is so named due to its propensity to precipitate out ellagic acid from the tanning solution, producing a product called 'bloom' and a large proportion of the tannin content of oak (*Quercus sp.*) is ellagitannin (Covington 2011: 286). Gallotannins have a smaller molecular weight than ellagitannins and are found only in higher order plants, one of which, Sumac (*Rhus typhina*) has been used as a commercial source of tanning material (Bickley, 1991). Some advantages of hydrolysable tannins is that they produce a light coloured tan and do not darken in sunlight (Covington, 2006). Condensed tannins occur in even primitive vascular plants and are referred to chemically as 'proanthocyanidins' (Bickley, 1991: 17). Unlike the pyrogallol tannins condensed tannins do not undergo hydrolysis, they instead 'precipitate, an aggregate of polyphenol molecules, called 'reds' or Phlobaphenes' (Covington, 2006: 25). Due to their structure they can undergo oxidative cross linking which results in a marked darkening when exposed to sunlight. All of the tannins possess phenolic hydroxyls which react with the collagen peptide links via hydrogen bonding, and secondarily, depending on pH, can fix to amino and carboxylic acids groups on the collagen side chains (Bickley, 1991; Khanbabaee and van Ree, 2001; Reed, 1972; 1966; Covington, 2011). These bonds formed with the collagen, effectively cross-link the dermal fibres as well as deposit solid aggregates of tannin particles between the fibres, which prevents the collapse of the fibre structure (Reed, 1972: 78). The reactions of the various vegetable tannins used in numerous variations of modern vegetable tannage are more complex than this research can cover. In depth publications are available from the authors referenced in this section.

In order to introduce tannins into the skin samples in a controlled manner, they are added initially to a weak tannin solution, and the concentration of the tannins gradually increased. This avoids the detrimental occurrence of case hardening the skin. Case hardening occurs when the outer layers of the skin become densely packed with tannins before the centre of the skin is fully tanned (Reed, 1966: 239; Covington, 2011: 295). The fully tanned outer surface prevents any further tannin from reaching the centre of the skin, leaving an untanned or raw stripe through the middle of the skin's thickness. The rawhide centre gives this type of leather a very stiff handle which persists even after being worn extensively, as the linear laminations present in the rawhide are very

Figure 4.4-1a and 1b. A- Oak bark being processed in a large wooden mortar. The large strips as they were pulled from the tree (left hand side of photo A), B- the size after crushing.

resistant to softening. However, this is detrimental when a soft product is desired.

In order to avoid case hardening, the water from the 3rd boiling was poured into a large plastic container, and then an equal amount of fresh water added to it before submerging the samples (Figure. 4.4-3a-b). This solution was increased in strength every 24 hours, first adding full strength 3rd boil solution, then full strength 2nd, then full strength 1st over the course of 4 days. The solution and the suspended samples were agitated (stirred or shaken) every hour during the day for the first two days, then stirred well each time a new solution was added. After the solution was brought up to full strength, it was stirred morning and evening. Tannin absorption was monitored twice a week starting after the third week in the full-strength solution. This was done by cutting a thin slice from a corner of the thickest part of each sample (Figure. 4.4-3c). When the colouration had permeated the entire thickness, and no light-coloured stripe remained, the samples were removed. Batches which contained thicker skins were left in the solution longer than those containing thinner or more loosely fibred skins. Figure. 4.4-2 gives the time spent in the tannin solution details for each species. For samples which remained in the solution for longer than 1 month, a fresh batch of fresh full strength 1st boil solution was added after 4 weeks.

After full tannin absorption was noted, the samples were removed from the solution, rinsed in clean water to remove any bark sediment, and preserved either frozen or dried until a later date, when they could be softened as a batch. The different preservation methods do not appear to have had any impact on the finished product, either in the ease of softening or microscopic appearance. Samples which were preserved by drying were damped back by rolling them up in a damp towel and leaving them to rest. The vegetable tan samples readily absorbed water, and none took more than a few hours to rehydrate. Samples which had been frozen were thawed then rolled up in dry towels and trod on to remove excess moisture until they were merely damp.

Species	Days	Species	Days
American Badger *Taxidea taxus*	**30**	Mule Deer *Odocoileus virginianus*	78
Beaver *Castor Canadensis*	30	Pronghorn Antelope *Antilocapra americana*	78
American Bison *Bison bison* Hair On	126	Rabbit *Sylvilagus sp*	30
American Bison *Bison bison* Hair Off	126	Red Deer *Cervus elaphus*	78
Big Horn Sheep *Ovis Canadensis*	data unavailable	Red Fox *Vulpes vulpes*	30
Black Bear *Ursus americanus*	30	Reindeer/Caribou *Rangifer tarandus* Hair on	58
Canadian Lynx *Lynx canadensis*	21	Reindeer/Caribou *Rangifer tarandus* Hair off	58
Elk *Cervus Canadensis*	78	Roe Deer *Capreolus capreolus*	78
Exmoor Pony *Equus ferus caballus*	78	Soay Sheep *Ovis aries* Hair off	78
Fallow Deer *Dama dama*	data unavailable	Soay Sheep *Ovis aries* Hair on	30
Galloway Cow *Bos taurus*	78	Toggenburg Goat *Capra aegagrus hircus* Hair on	30
German Shepard *Canis lupus familiaris*	30	Toggenburg Goat *Capra aegagrus hircus* Hair off	30
Moose *Alces alces*	78	Wild Boar *Sus scrofa*	125

Figure 4.4-2. Number of Days in Tannin Solution for Each Sample.

From this point onward the dried and frozen samples were treated identically. Neatsfoot oil was used to lubricate the fibres of the skin, which adds strength and elasticity to the dermal structure. This process is often referred to as 'stuffing' or fat liquoring in commercial tanning literature and any number of oil and fat combinations have been used in this process (Reed, 1972; 1966; Covington, 2011). The neatsfoot oil was poured onto a rag and rubbed into only the flesh side of the hair-on samples and both the flesh and grain sides of the hair-off samples, while both sets were in the fully damp stage. The samples were then softened by working them between the hands, over a staking post and by pulling them through a cable. The cable had to be used gently and only on the flesh side as the rubbing would mar the grain, and any overenthusiastic pulling could cause tears or cracks to appear in it. The grain layer is less elastic than the fibre network (mid-dermal) layer and will fail during stretching if care is not taken to judge the force necessary to manipulate the fibres without damaging the grain. When the samples were at a three quarters dry stage, another coat of oil was applied to the flesh side of the hair-on samples, and only to the grain side of the hair-off samples. If applied to the flesh side of the hair-off skins at this stage, the oil left dark blotches on both surfaces, which, while not detrimental to the softening process, were unattractive. To speed the drying process some of the thick samples were put in the tumble dryer on the no heat setting for 10 minutes at a time. Vegetable tan withstands heat better than the other tannages covered by this project, and the author has previously used the low heat setting to speed the drying process with no detrimental effects, though to be clear, no heat was used with the samples. No samples needed to be damped back and softened a second time.

4.5 Alum Tawing

All species and samples were de-fleshed over a beam, washed, and then the hair-off samples placed in an alkaline solution, as described in the reduction treatments section. When the skins had reached the stage where the hair had loosened, the samples were removed from the alkaline solution and de-haired using a wooden tool with a blunt edge to push off the hair without damaging the grain surface. All samples intended to be hair-on were placed in the alum solution directly after fleshing or, were frozen to be added as a batch at a later date. All hair-off samples were neutralized and rinsed before being placed in the alum solution.

Figure 4.4-3a and 3b. A- Fur samples showing suspension method. B- Cross section of bison skin showing the white strip indicating and untanned centre.

Alum ($KAl(SO~4)_2 \cdot 12H~2O$) is a double mineral salt composed of aluminium and potassium sulphates which precipitates out of alum shale, which is comprised of bitumous clay, in many warm climates around the world (Reed, 1972: 62; Haines, 1991c: 26). It is the only mineral tannage in use prior to the industrial revolution which saw the rise of chromium and aluminium tannages in the mid 1800's and 1900's respectively (Thomson, 2009; 1991b). When added to skin alum produces soft, white, stretchy leather with some unique characteristics including, an inability to absorb synthetic dyes (only natural ones can be used) and its utter incompatibility with water and wet conditions (Haines, 1991c; Rahme, 2006; Thomson, 2009). If wetted, alum tawed skin will revert to a stiff, unprocessed state due to the solubility of the salts contained within the fibres. The active tanning agent in alum is aluminium (III) for which the reaction sites on the collagen are the carboxlys. These reaction sites do not form stable covalent bonds however, and are instead, predominantly electrostatic in nature, which explains the ease with which they hydrolyse allowing the salts to wash out of the skin (Covington, 2006: 269).

While an adequate tan can be produced with alum alone, it is most often mixed with common salt (Sodium Chloride (NaCl). Though not strictly necessary for the tawing process, salt is added to combat bacterial growth and as a reagent which affects the thickness (or substance) of the finished product (Reed, 1972: 62). This is due to salts ability to counteract the swelling of collagen in acidic conditions (alum being slightly acidic) (Covington, 2011: 268). In addition to salt a fat liquoring agent is needed to lubricate the fibres of the skin before it can be adequately softened. The fat emulsion used must be stable to alum however, as aluminium (III) reacts with fats and oils and precipitates them out as aluminium soaps (Haines, 1991c: 26). Traditionally this substance has been egg yolks, which, similar to brain tissue, contains lipids in a highly emulsified state due to its high content of phospholipids (Landmann, 1991).

For this research the alum was prepared as an aqueous solution, though it can also be applied as a paste (Covington, 2011; Thomson, 2009). In this case 500 grams (approx. 2 cups) of alum were added to 12 litres (approx. 3 gallons) of water along with 250 grams (approx. 1 cup) of salt. The commercial crystallized alum purchased for this project mixes much more quickly and thoroughly if the water is hot, preferably boiling. The alum was dissolved in 2 litres (1.8 quarts) of boiling water, which was then poured into a large plastic container containing the remaining 10 litres (2.2 gallons) of water. The salt was added after the alum was fully dissolved, and the alum bath had cooled to room temperature.

The samples were immersed in this solution and stirred twice a day, until the alum penetrated through the full thickness of the skin. The progress of the penetration was monitored using the same method as with vegetable tan, in that a small slice of skin was taken from a corner and the visual progress of the tan through the skin observed. The visual progress was checked every other day after the first 5 days in the solution, as the alum permeated the dermal tissue more quickly than did the tannins. In this case the progression of the tan was judged by the gradual disappearance of the yellow/cream colouration of the raw skin, being replaced by the bright white colour characteristic of alum taw. Most of the skins showed white centres within 10 days and were removed from the solution at this time. Leaving the skins in the solution longer than this has no detrimental or advantageous effects on the hair-off skins, however, there is some chance that slippage can occur, if hair-on hides are left in the solution longer than necessary. Based on this understanding, some later samples were not immediately removed from the alum solution after full penetration of the alum was noted, as the author was away for field work.

Figure 4.5-1. Alum taw skins crusting. From left: fox (*Vulpes vulpes*), dog (*Canis lupus familiaris)*, and black bear (*Ursus americanus)*.

Species	Solution	Crust	Species	Solution	Crust
American Badger *Taxidea taxus*	**6**	**70**	Mule Deer *Odocoileus virginianus*	13	85
Beaver *Castor Canadensis*	6	70	Pronghorn Antelope *Antilocapra americana*	13	85
American Bison *Bison bison* Hair On	19	90	Rabbit *Sylvilagus sp*	6	70
American Bison *Bison bison* Hair Off	19	90	Red Deer *Cervus elaphus*	13	85
Big Horn Sheep *Ovis Canadensis*	data unavailable	data unavailable	Red Fox *Vulpes vulpes*	6	70
Black Bear *Ursus americanus*	6	70	Reindeer/Caribou *Rangifer tarandus* Hair on	56	91
Canadian Lynx *Lynx canadensis*	16	57	Reindeer/Caribou *Rangifer tarandus* Hair off	56	91
Elk *Cervus Canadensis*	13	85	Roe Deer *Capreolus capreolus*	13	85
Exmoor Pony *Equus ferus caballus*	13	85	Soay Sheep *Ovis aries* Hair off	13	85
Fallow Deer *Dama dama*	data unavailable	data unavailable	Soay Sheep *Ovis aries* Hair on	6	70
Galloway Cow *Bos taurus*	13	85	Toggenburg Goat *Capra aegagrus hircus* Hair on	19	90
German Shepard *Canis lupus familiaris*	6	70	Toggenburg Goat *Capra aegagrus hircus* Hair off	19	90
Moose *Alces alces*	13	85	Wild Boar *Sus scrofa*	NA	NA

Figure 4.5-2. Number of Days in Alum Solution and Spent Crusting for Each Sample.

After removing the samples from the solution, they were allowed to air dry or 'crust' and left in this state for between 6 and 12 weeks (Figure. 4.5-1). Crusting appears to increase the bonds between the alum and the dermal fibres. This 'aging' helps to stabilize the tanning agents within the dermis and improve the resulting products resistance to wetting (Reed, 1972: 63). The length of time each sample spent in the alum solution and the number of days it was allowed to crust, are recorded in Figure. 4.5-2.

After crusting, the samples were damped back and then oiled with egg yolks which were frequently used for this purpose in very early historic recipes (Reed, 1972: 63). The manner in which the yolks are added to the skin is rather unclear in most recipes, so two ways were trialled. The first and most successful way, was to mix up 4 yolks with a whisk then spread this mixture on both sides of the hair-off samples. Next, the oils from the yolks were worked into the skins by mashing the samples in bowl and between the hands. The yolk mixture was applied only to the flesh side of the hair-on samples and worked only between the hands, in an effort to keep the sticky substance out of the fur. The second version involved whisking the yolks in a pint of warm water then immersing the samples in the solution. Unfortunately, this method appeared to rinse out a small portion of the alum salts, resulting in a sample that was more difficult to soften, and which had a yellower colour than that of samples oiled using the first method. After the yolk application the samples were left to dry until slightly damp, then were softened using the same techniques described for vegetable tan. No samples required a second round of yolk application.

4.6 Urine Tannage

All species and samples were de-fleshed over a beam, washed, and the hair-off samples placed in an alkaline solution, as described in the reduction treatments section. When the hair had loosened, the samples were removed from the alkaline solution and de-haired using a wooden tool with a blunt edge to push off the hair without damaging the grain surface. After de-hairing, the samples were neutralized and rinsed before placing in the urine container. All samples intended to be hair-on were put into the urine container directly after fleshing, or, were frozen to be added as a batch at a later date.

Urine appears too been used for skin processing in two ways. When used fresh, as is the case in a variety of arctic areas, it contains formic and uric acid (Rahme, 1996; 2006). Urea is capable of breaking hydrogen bonds and can partially destabilize collagen, as well as provide a mild alkaline effect due to the breakdown of urea into ammonia (Graemer, 2006: 177). When used aged the ammonia produced is a potent degreasing agent, which can be used to good effect during the reduction treatments to remove excess oil from the

Figure 4.6-1. Hair-off samples soaking in the urine solution. (Looking down into the solution).

dermal structure, which would otherwise go rancid, as well as open up the fibre structure to allow more even penetration of tanning agents (Graemer, 2006).

Urine is also a well-known additive to the bating solutions in use up until the early 1900's, when they were replaced by proprietary compounds produced from pancreatic enzymes (Covington, 2011: 166). Urine, as a biologically active liquor helped to produce 'a complex mixture of organic acids and enzymes which dissolved the non-fibrous protein of the skin' (Thomson, 1991: 13). This enzymatic effect may explain the lessened tendency for grain cracking seen with this method, when compared to past grain-on fat tans produced by the author. By breaking down the keratin and elastin in the grain layer, the layer's ability to stretch, in relation to the rest of the dermis during softening would be improved, resulting in a less damaged grain surface. Other than the noticeable mitigation of grain cracking, the urine treated skins were overall the most difficult of the fat tanned samples to soften, bringing into question the active tanning capabilities of urine treatment.

The use of fresh urine as a tanning agent is more pronounced in arctic areas. In many areas, there are ethnographic accounts where a cultural preference for urine from specific age groups or genders is mentioned (Rahme, 1996: 39). However, for this project, the author's collection options were limited to adult participants. Morning urine was collected over the course of a month and frozen until use. The preference for morning urine, due to concentration, is in keeping with the ethnographic literature (Issenman, 2011; Oakes and Riewe, 1995). All samples were immersed in the urine container for 4 days, during which they were agitated 2 to 3 times per day (Figure. 4.6-1). Each morning the stale urine was exchanged for fresh urine. After 4 days, the samples were removed from the urine and rinsed in several changes of clean warm water, which removed any precipitates and reduced the urine odour. However, as the solution was changed each day none of the samples were particularly strongly scented. Samples were either softened immediately or, frozen till a more convenient time.

To begin the softening process, the samples were rolled in towels and trodden on to remove excess water from the fibre structure, and for hair-on samples, this dried the fur to a great extent as well. When the samples reached a barely damp stage, neatsfoot oil was rubbed in using a rag. Both the flesh and grain side of hair-off samples were oiled, while only the flesh side of hair-on samples were oiled. They were then worked dry using the same softening techniques as detailed in the vegetable tan section. When approximately three quarter dry, the samples were given a second coat of neatsfoot oil. This was applied to only the grain side of the hair-off samples, and only the flesh side of samples with the hair left on. Softening continued in the same manner used for alum taw until the samples were fully dry. A number of the thicker skins required multiple softening cycles, which involved re-dampening the stiff samples then re-oiling and reworking before a fully soft product was produced. Neatsfoot was chosen as the dressing agent as it not known to oxidise and create a fat/oil tan as seen with brains, egg yolks, cod oil and other fats/oils used for this tannage technology. This allowed the urine's tanning capability alone to be better assessed.

4.7 Rawhide Method

All species and samples were de-fleshed over a beam, washed, and then the hair-off samples placed in an alkaline solution as described in the reduction treatments section. When the hair had loosened the samples were removed from the alkaline solution, and de-haired using a wooden tool with a blunt edge which pushed off the hair without damaging the grain surface. After de-hairing the hair-off samples were neutralized and rinsed. Hair-on samples were dried immediately after being de-fleshed.

The samples were then tacked out using small nails to stretch the samples flat on a sheet of plywood. Making sure the flesh side faced the woods surface to avoid marring the grain pattern for hair-off samples. For the hair-on samples the fur was towel dried to speed drying and avoid any slippage. If, however, the fur on the hair-on sample was already dry (this being the case in furs which did not require washing), then the samples were tacked out with the hair side facing the wood, in order to dry the dermal tissue as quickly as possible (Figure. 4.7-1a and 7b). The samples were left in a warm dry space to dehydrate. When completely dry the nails were removed and the samples were placed in protective plastic sleeves and labelled for storage.

There is little chemistry involved in the processing of rawhide. It is instead a process whereby the mucopolysacharides and interfibrillary proteins which make up the ground substance are allowed to act as a glue as the fibres of the skin dehydrate. It very effectively re-sticks the fibres into a dense, hard state which is often transparent. Rawhide has strong hydrophobic tendencies and once well dried it is difficult and time consuming to rewet. This tendency can be strengthened by the application of an oily or waxy coating to the surface of fully dried rawhide products. Rawhide is renowned for its properties of impact and abrasion resistance combined with elastic resilience and is today still used to reinforce the corners of the baskets on hot air balloons (Thomson, 2006).

Figure 4.7-1a and 1b. **A**- Rawhide- Hair-off: (left to right) horse, elk, soay sheep, moose, cow. **B**- Furs: (left to right) fox, bear, rabbit, soay sheep, beaver, badger.

4.8 Discussion

A number of issues which arose during production of the sample collection were noteworthy, some problematic, some advantageous. They fell roughly into three categories; general issues which could affect any species and tannage type, those related to one specific tannage type, and those related to a specific species.

The majority of detrimental general issues were caused by less than ideal curing of the skin, when in the hands of the skin's original processor. The most frequent issue encountered was poor skinning, which results in skins with unnecessary holes or scores, (scores being cuts through the partial dermal thickness which often become holes during the scraping or softening process). Secondly, poorly fleshed or cleaned skins produced a couple of grease related issues. Incomplete removal of surface fats from the dermal tissue before fully drying a skin results in a difficult and time-consuming rehydration process, as the spaces between the fibres are filled with water repellent heavy fats. If these fats were then exposed to sunlight or warm temperatures for a given amount of time, a second problem, commonly called grease burning occurs. This occurs when these fats partially putrefy damaging the structural integrity of the surrounding dermal network (Rahme, 2006: 41; Richards 2004: 51). If a skin is going to be preserved (cured) for storage by drying, large scale bruising can cause similar damping back difficulties to grease, if the leaked fluids responsible for bruising are not thoroughly rinsed out before the skin is dried. Decay, either prior to skinning a carcass or later, during the curing or storage stages, can have some interesting effects on the resulting product. Obviously, excessive putrefaction renders the skin unusable as the fibre network breaks down and the skin pulls apart like a wet paper towel. In mild weather, however, a few days on the side of the road will cause the hair to slip but the dermal tissue will still be usable, if a bit odiferous. There is a point along this sliding scale, from fresh to unusable, where the grain can sometimes detach (delaminate), from the underlying fibre layer. This unfortunately, occurred for the pronghorn samples used for this research. The skin was retrieved from a carcass in less than prime condition, by a third party. Had the skin not needed to be imported from another continent a replacement would have been sought.

Natural skin defects were also encountered, including, barbed wire fence scarring along the back of North American ungulate species, and bot fly scars on both red deer and reindeer. Bot flies are members of the *Oestridae* family and lay eggs on the hair of large mammals. When the larvae hatch, they burrow into the skin where they develop. At maturity they drop out of the host animal, pupate in the ground and repeat the cycle the following year (Colwell *et al.*, 2006). The holes made in the skin and the scar tissue surrounding them can severely impact the skins character. Aesthetically, the holes change the look of the grain surface, but more importantly each small area of scar tissue inhibits the absorption of tanning agents and oils, and resists softening, resulting in a skin with myriad small hard spots. Though not found to be detrimental to the skin quality, ticks were found on most skins and in the case of moose, in a rather disturbing quantity.

A more advantageous general observation is that of aged skins versus recently cured ones. Skins which had been dried for extensive periods of time, some up to six years, softened much more easily than more recently acquired ones. This appears to be a result of the ground substance breaking down over time, making it easier to remove from the dermal network. This in turn, made for more efficient and complete penetration of the tanning agents. An interesting neutral observation pertains to skin thickness between wild and domestic members of the canine and feline families. There is a distinct general tendency for the skins of wild canine and feline species to be thinner than domestic cat and dog skins. This tendency toward a more robust dermal thickness has been noted in a number of different domestic cat and dog breeds. Domestic dog skins work soft very easily compared to other fur bearers, which and may have contributed to their status as the once preferred material for riding gloves (Covington, 2011: 36).

Another general rule worth mentioning here is the thicker the fur is, the thinner the dermis normally is. This variation even exists within a single species such as red fox (Vulpes vulpes), where individuals taken from more northern climates have significantly thinner skins than those from more southern, warmer climates.

Other noteworthy observations were specific to each tannage type, or one of the reductive treatments. The first is to do with hair and grain removal by dry scraping. As mentioned before, the dry scraping tool shaves off the hair and grain and for species whose hair shafts terminate at a shallow depth there is no issue. However, for species where the hair roots penetrate deeper into the fibre layer these roots are left behind when scraping. Both cow and wild boar suffered from this complication. Interestingly during the softening process, the bone tool pushed these roots out from the follicles quite effectively, a process known as 'scudding' when done over a beam.

When de-hairing in the alkaline solution, both wild boar and bison proved to have fur which was more firmly set in the follicles than other species. Neither was effectively de-haired using this method. Both were left in the solution for two weeks, after which the bison skin showed a few patchy areas of hair loss and only the underfur from the wild boar was able to be removed. The bristles or guard hairs of the boar skin remained firmly in place. It was necessary to neutralise both samples, then place them in multiple layers of sealed plastic containers in a warm domestic environment, for a 3-day period. This controlled rot, referred to as 'sweating' finally allowed full de-hairing to take place. While this level of difficulty was understandable for the boar, with its deep-seated hair follicles, it was unusual for the bison. It is the authors opinion that this difficulty may not apply to the species as a whole, but is instead isolated to this particular specimen, as there exists no readily available explanation, based on the species skin or hair morphology, to explain this occurrence.

Urine tan worked reasonably well on thin skins but not as well on thicker skins. However as mentioned, it does appear to mitigate some cracking of the grain surface seen in past attempts at grain on fat tans. Of the tannage types covered by this project it had the highest incident of slipping and delamination of the grain layer. The hair-on Toggenburg goat sample, had the majority of the grain layer separate from the fibre layer, and slipped badly enough that it was discarded. Reindeer and rabbit also showed some slippage of the fur, and the hair-off goat sample had a small area of grain separation as well. After processing over twenty samples using this method, and based on the microscopic analysis, this is best thought of as a variety of fat tan not a separate tannage in its own right.

Bark or vegetable tannage was very consistent across the different species, and the only noteworthy point worth was the build-up of a layer of gelatinous slime on the surface of the solution. It needed to be removed occasionally as it impeded the stirring process and produced a dark coloration on samples whose top edge were in contact with it for an extended period of time. It appears to be composed of fats or oils from the skins which mould or mildew where they sit on the solutions surface and come into contact with oxygen.

Alum taw was again quite consistent as a tannage, however, both rabbit and Soay samples showed some small areas of slippage. This may have been due to the solution staying a bit too warm or simply not stirring often enough to make certain the salt and alum penetrated through the dense and, in the case of the Soay sheep, oily fur.

The dry scrape method of de-hairing/graining and working soft certainly produces a nice product however; it requires extra work, time, supplies and a more technologically advanced tool set than the wet scraping method. It is, however, advantageous for certain situations. It is easier to keep a furbearer's coat clean using this method if the species is thick skinned, or tough enough to resist tearing when laced into a frame. Large, thick, or heavy skins are much more manageable when dried in a frame in terms of weight and manoeuvrability. The use of a frame also offers the option of scraping large hides a little at a time, whereas with wet scraping, unless you have a large freezer, the skin needs to be finished in a shorter time scale. This can be mitigated by using the alkaline 'bucking' solution for de-hairing, as the skin can be put back into it repeatedly to break up the work of de-graining, which is, perhaps the most labour intensive step of fat tanning. For thinner skins the wet scrape method is preferred as it is more time efficient, the tools are easier to make and maintain and a percentage of the skin is not lost to the lacing holes. Very thin skin can only be wet scraped as they tear too easily to withstand being strung into a frame. One way to circumvent this problem is to case-skin a thin skinned species like a fox, turn the skin inside out and slide it over a an A shaped frame of willow or wire, where it can be carefully de-fleshed and left to dry.

The majority of the discussion about specific species, has been covered by the discussion surrounding specific tannage types. However, a few species need mentioning. The rabbit skin used for the collection is of an unknown age and sex. Based on the difficulty encountered in softening what is normally a reasonable species to work with (apart from de-fleshing), the author believes this to be a very old, male rabbit. It is not a good general representation of the normal amount of time and effort which goes into tanning a more average rabbit skin. The specimen acquired for the horse sample is also notable in that it was only a few days old at the time of death. It had a very thin skin with an exceptionally tight fibre structure, and a distinctive cross hatched membrane layer which was very difficult to remove. This layer may allow the horse to twitch its skin to rid itself of insects. It was also difficult to de-grain as this layer was very thin. There was a very fine line between applying enough force to remove the grain, and too much which would tear holes through the thin dermis.

4.9 Conclusion

This chapter sought to present, not only, the factual methodology undertaken for the production of the comparative sample collection, but also a brief overview of the chemistry behind each tannage type. While this overview by no means exhausts the complexity of the processes at work for the various tannage types, it is hoped that it conveys a basic understanding of the major interactions between tanning agents and collagen, for vegetable, fat, smoke, and urine tanning, as well as alum tawing. The tannage technologies detailed here were used to tan a sample section of skin from each of the 22 species selected and sourced for the comparative collection. This collection currently contains 155 samples, which, after completion of the tanning portion of the research, were analysed in an effort to identify both macroscopic and microscopic differences between the tannage types. The methodology for the identification and recording of these discriminating traits follows in chapter 5.

Chapter 5

Analysis of Experimental Reference Sample Collection

5.1 Introduction

The sample collection produced using the six different tanning methods outlined in chapter 4 and the 23 species discussed in chapter 3, was analysed to establish whether identifiable differences between the tannage types could be identified and recorded both visually and descriptively. Both macroscopic and microscopic attributes were considered during this analysis. A short synopsis of the methodology used to identify, measure and record each criterion is given prior to the presentation of the data tables. The criteria with which the sample collection was analysed are illustrated photographically, and the specific analysis for each sample is also presented in tabular form, supported by written descriptions. In many cases, ordinal scales were used as a method of standardising the qualitative portion of the data set. The data sets are relative not definitive, and the emphasis is on the replicability for future researchers, not on statistical validity.

The following analysis of the experimental sample collection is divided into four sections; macroscopic observations, microscopic surface observations of the flesh and grain sides, microscopic cross section analysis, and individual fibre analysis. Interpretation of the data sets is covered in chapter 6.

5.2 Macroscopic Analysis

Upon completion of the sample collection, a series of macroscopic characteristics were noted. These characteristics include colour, surface texture, pliability, stretch, light translucence and UV reactivity. As a way of reviewing these characteristics in a more structured way, a set of standardised identification pictures for each classification criterion was assembled. These photographic sets outline the visual differences in a standardised way for comparable future research. Multisensory and interactive attributes such as stretch, and surface texture designations are difficult to convey. To help mitigate this images and descriptions are given for these more tactile classifications.

In addition to these qualitative assessment sets, ordinal evaluation scales were devised for both pliability and stretch. As each characteristic's value is allocated, and the differences between them are not quantifiable, ordinal scales can assign values which represent the rank order of each characteristic in relation to each other as stated by (Stevens, 1946) on page 697. This allows for an accurate assessment of variation within each characteristic set in a standardised way.

Though the characteristics recorded were deemed important as indicators of tannage type, there are still other layers of importance for visual characteristics. The simple aesthetic value placed on the different surface textures and colours by past peoples may have played a role in the tannage type chosen for a given use, even without the differing physical properties of each tannage type being taken into account. A summary of each characteristic and its possible implications to everyday use follows.

Colour

Each sample piece was given a colour designation, with white and dark brown marking opposite ends of the scale. These, plus the other colour options covering the range of variation between these two extremes, are illustrated in Figure. 5.2-1. The colour options are shown next to one another to give a clearer sense of the variation. All are shown from the grain side for consistency.

The grain and flesh sides of both wet and dry scrape brain tan were very close in colour and as such were not recorded separately. However, the other tannage types had enough colour difference between the two surfaces to warrant recording both. A few samples had brown spots, and this was added as an additional category (Figure. 5.2-2)

In addition to the brown spots seen on certain samples, another designation specifically for describing a portion of the rawhide samples was needed. When rawhide is dried under moderate tension, when fully saturated, and not manipulated at all during the drying process, it dries translucent. Translucency is illustrated by Figure. 5.2-3.

Surface Texture

This particular criterion may have more to do with the softening process employed for the flesh side, and to some degree the species being tanned for the grain side, than the tannage technology used. However, as the surface texture differs significantly from sample to sample, it was included in the diagnostic process. That being said, some surface texture differences, mainly the presence or lack of the grain layer, may give some indication of the tannage type used. While fat tans processed with the grain layer intact do exist, and do produce soft skins, this is only possible with relatively thin skins, and even these are not as soft as those that could be obtained by removing the grain. Softness or pliability are of course not the only concern and leaving the grain layer on does have some advantages. The grain layer inhibits the amount of stretch the skin has, which is an advantage for straps or other pieces of equipment, in which an overabundance of stretch is detrimental to their function. The grain side can also be more effectively oiled to form a water-resistant surface. The disadvantages to a grain on leather are a greater tendency to tear, and an oiled grain on skin has a reduced ability to breathe and is heavier. For a more detail on these variations see page 4 in Chapter 2. Figure. 5.2-5 shows the various surface textures encountered in the experimental sample collection.

Two of the tactile criteria – 'rough and scratchy' and 'slightly rough and scratchy' – are often caused by the hair roots pulling through the flesh side surface. Many of the furbearing animals have relatively thin skins, and with some species the scraping process can pull a small percentage of the hair through the thin dermis (Figure. 5.2-4). Others have such thin skins that the hair roots are simply detectable by touch through the dermis.

Membrane Remnants and Fibre Rolls

Membrane left on the flesh side during the fleshing process can influence the pliability, stretch, colour and texture of the finished skin product (Figure. 5.2-6). An excessive amount of overlooked membrane can inhibit the penetration of oils and smoke, as well as inhibit the travel of tannins and alum to the interior of the skin. Though most of the samples had very little remaining membrane, it was still recorded to assess any impact on the final product it might have. Fibre rolls are compressed rolls of fibres and in some cases membrane remnants formed on the flesh side of the skin during the softening process. This seemed more dependent on the softening method than on tannage type. Though tannages where oils or emulsions were added in the later stages of the processing sequence, such as alum taw, formed denser fibre rolls. The species also appears to influence the amount of fibre rolls formed, and on this basis, it was recorded as well.

Light Translucency

Perhaps one of the most interesting macroscopic differences between the tannage types was the degree of light translucence exhibited by each. Rawhide, both brain tans, alum taw and urine tan all allow light to shine through the skin. This tendency was not affected by the grain being intact or removed, and even very thick skins showed light translucency when in a room with dim light. Vegetable tan, however, does not transmit visible light through the dermal thickness, even in thinly cut cross sections. A wet scrape brain tan over dyed with Black Walnut (*Juglans nigra*) hull powder also allowed for no visible light to pass through (Figure. 5.2-7). This strongly suggests that the tannins distributed within the dermal matrix are responsible for this distinctive characteristic.

Stretch

The amount of stretch a given tannage type imparts to the final processed skin product has important connotations for its use. Stretch can be a useful characteristic for a comfortable fit and ease of movement in clothing. It can, conversely, be detrimental in that clothing can stretch too much, until seams are no longer tight, waistlines loosen, and knees and seats of trousers sag. Loose seams and waistlines are true functional difficulties. It might be argued that garments which have stretched into aesthetically displeasing proportions are not something with which early peoples would have concerned themselves. However, the evidence of decoration by early peoples indicates that they did concern themselves with aesthetics, and clothing would be an obvious medium for expressing this (d'Errico *et al.*, 2003; Vanhaeren *et al.*, 2006; Gilligan, 2007). Having very little stretch is advantageous for belts, shoes, bags and straps of all kinds. Anything which would undergo heavy strain is best constructed from a material with less stretch. An end product with no stretch at all is necessary for hard sided containers, shields, doors, and lashing. So, while rawhide is not an important tannage type in the dialogue surrounding ancient clothing, with the exception of shoes, it is very important when talking about utilitarian items and construction elements. Figure. 5.2-8 is the author's attempt to visually capture the range documented within this criterion.

Pliability

For assessing pliability in the experimental sample collection an ordinal scale was designed. Pliability is perhaps the most important characteristic in the construction and performance of complex tailored garments. It plays a pivotal role in effectively trapping air while allowing the wearer freedom of movement. The softness of the material allows for more complex patterns with tighter seams, which inhibit air movement and the consequential heat loss this causes in untailored or draped clothing (Cook, 2013; Gilligan, 2007; 2010).

The ordinal scale used to assess pliability for this research is based on scales established for a South African study looking at the efficacy of red ochre as a hide tanning ingredient (Rifkin, 2011). Rifkin's scales were based on the incidence of cracking or splitting at folding zones. These criteria were perfectly adequate for this study where the majority of the samples fell into the stiffer end of the processed skin spectrum. For this research, where the goal of tanning was to produce the best quality product each tannage type would allow, the majority of the skins were very soft. It was decided that a more nuanced pliability scale skewed toward the softer end of the processed skin spectrum was needed.

In keeping with the goal of replicability, the descriptions of 'Drape' for each sample were assessed by laying them over the top of a ball point pen (with the cap in place). A pen was chosen with the understanding that this common item would be easily accessible for future researchers. The designations for pliability are visually presented in Figure. 5.2-9.

Ultraviolet Light Reactivity

Each sample's surface and a freshly cut edge was exposed to Ultraviolet light and its level of reactivity recorded. The ability for collagen to fluoresce under UV light is known, as is the same reaction for tannin. Interestingly, however, when combined – as is the case with vegetable tans – the resulting product does not fluoresce (Reed, 1972: 255). This is a useful way to test for tannins in archaeological material, which has not been exposed to tannins in the depositional environment. It will pick up the presence of tannin-based dyes as well, which have little to do with the initial skin processing undergone by the artefact. This limits its use as a diagnostic tool for tannage determination, but it is still useful in assessing the penetration depth of tannin-based dyes. The mid dermal tissue which was not exposed to the dye or stain may fluoresce. This is also the case when dealing with short soak vegetable tans, where the tannage may not completely penetrate the full dermal thickness. In the case of some of the thicker samples, a thin strip fluoresced in the middle of the dermal thickness, indicating incomplete tannin penetration due to the short soaking times in the tannin bath. A camera capable of taking pictures of this criterion was not available, and as such this characteristic was unable to be photographed. Both light translucence and UV reactivity for each sample are summarised in tables Figure. 5.2-10 through Figure. 5.2-15.

The macroscopic criteria recorded for each sample, excluding 'Light Transparency and UV Reactivity' are consolidated into tables (Figure. 5.2-16 through Figure. 5.2-21).

Macroscopic Criteria Identification Photographs

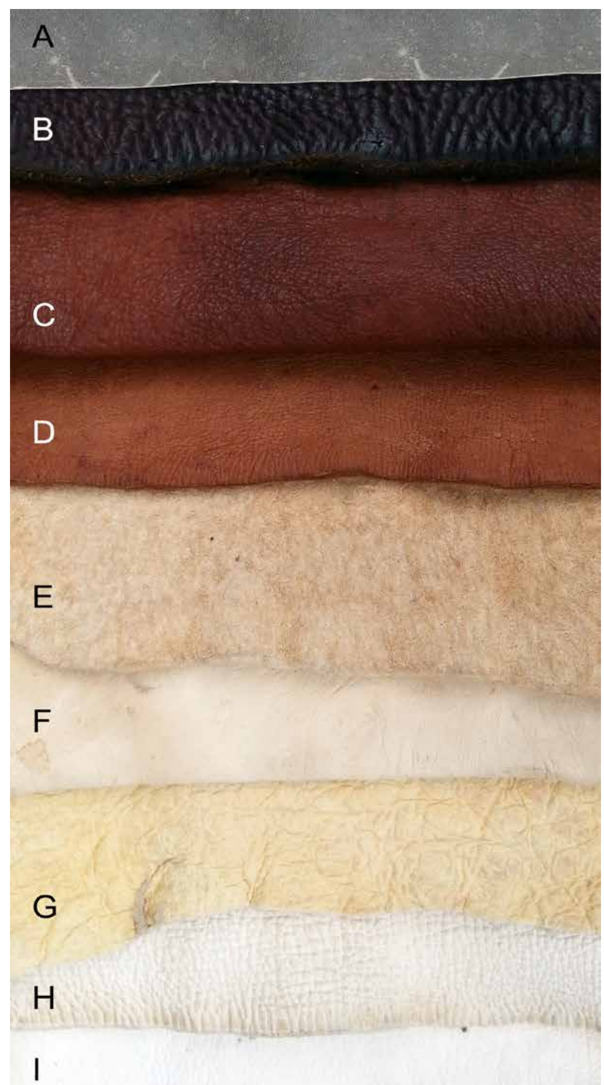


Figure 5.2-1. Colours Designations: **A**-Translucent, **B**-Dark Brown, **C**-Red Brown, **D**-Light Brown, **E**-Golden Tan, **F**-Light Golden Tan, **G**-Yellow, **H**-Cream, **I**-White.

Figure 5.2-2. Brown Spots on Various Species and Tannage Types: Top- Vegetable tan Fallow Deer (*Dama dama*), Bottom left- Urine tan Big Horn Sheep (*Ovis canadensis*), Bottom right- Alum taw Red Deer (*Cervus elaphus*).

Figure 5.2-3. Transparency in Rawhide.

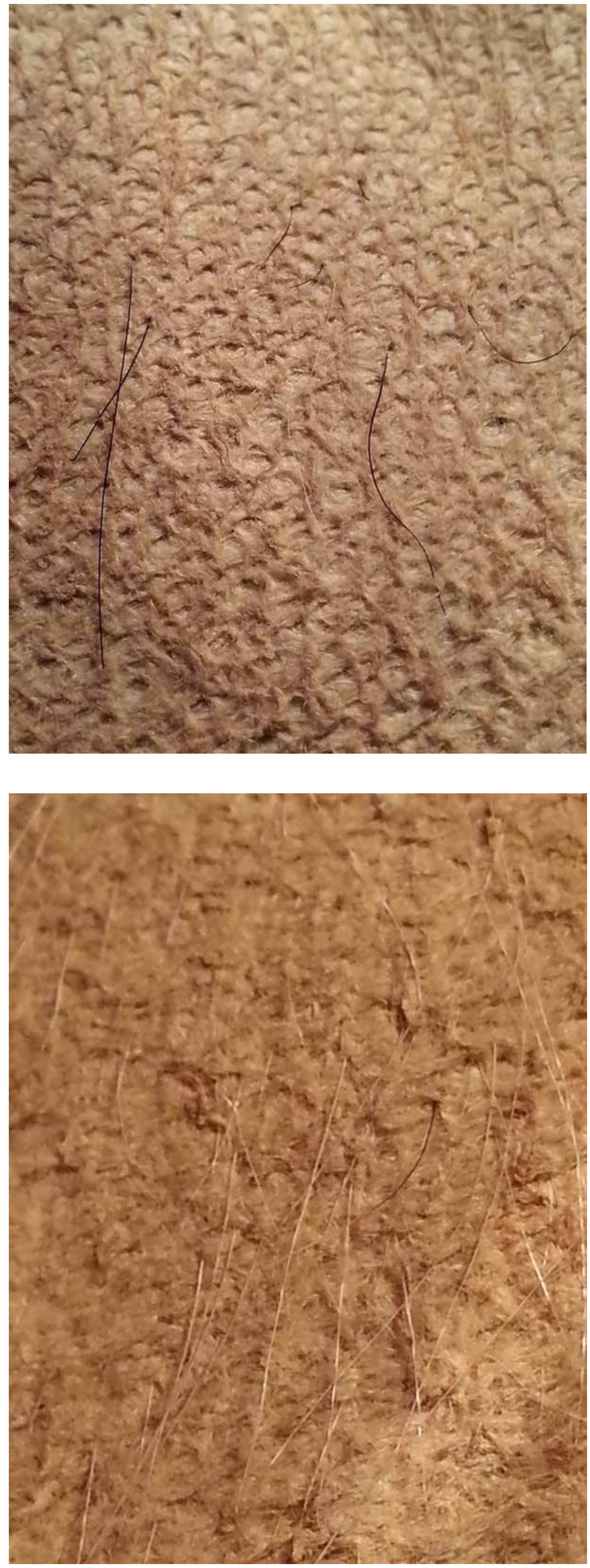


Figure 5.2-4. Hair Pull Through- Top: German Shepherd (*Canis familiaris*), Bottom: North American Badger (*Taxidea taxus*).

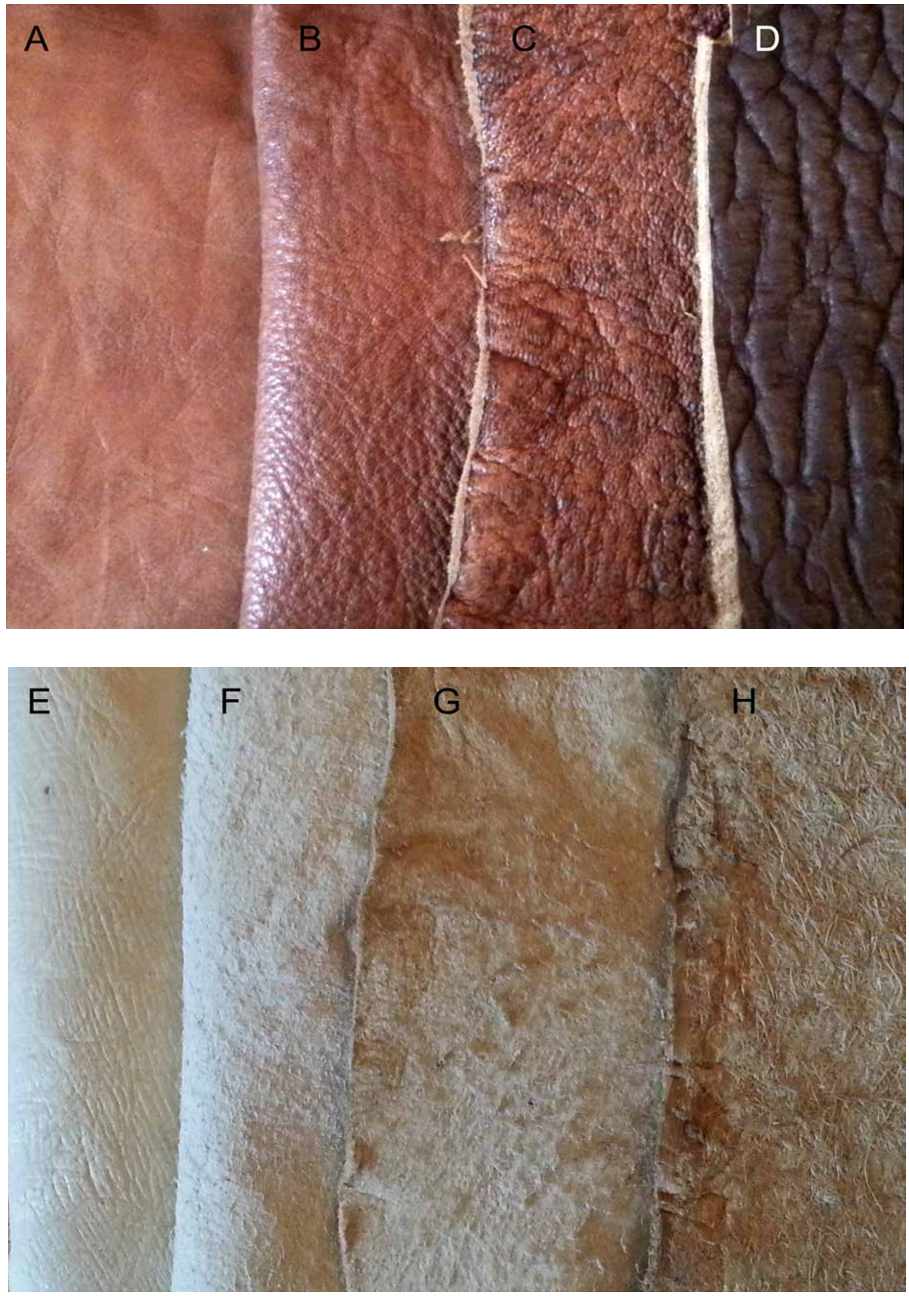
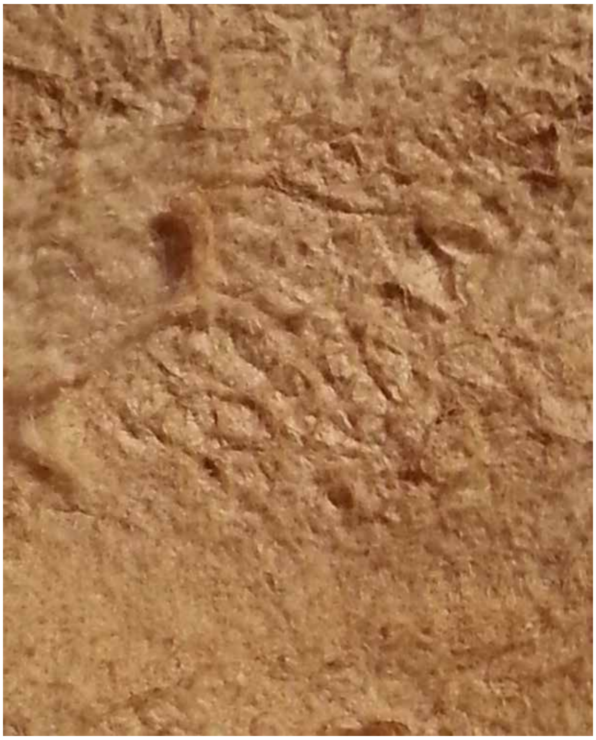


Figure 5.2-5. Surface Textures- Top Row (with grain-on): **A**-Smooth, **B**-Slightly Textured, **C**-Moderately Textured, **D**-Heavily Textured. Bottom Row (with grain-off): **E**-Smooth, **F**-Very Lightly Fuzzy, **G**-Lightly Fuzzy, **H**-Coarsely Fuzzy.



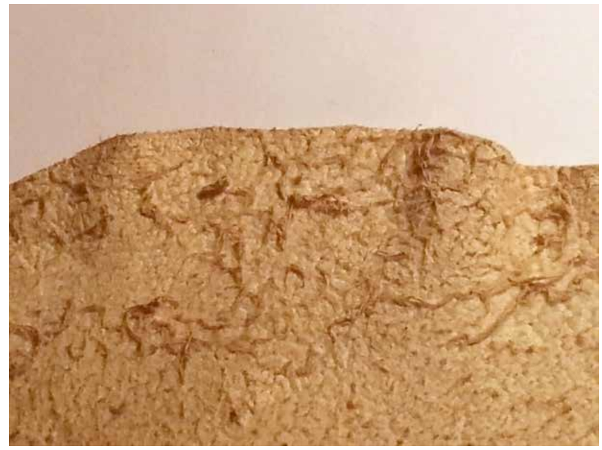


Figure 5.2-6. Left: Membrane Remnants on Pronghorn Antelope (*Antilocapridae americanus*). Right: Fibre Rolls on Roe Deer (*Capreolus Capreolus*).

Figure 5.2-7. Light Translucence in different tannages. (**A**): Wet Scrape Brain Tan, (**B**): Bark Tan, (**C**): Combination Tan (Brain with Black Walnut over tan).

Figure 5.2-8. Visual Demonstration of Stretch: Top left: Very Stretchy, Top right: Stretchy. Bottom left: Little Stretch, Bottom right: No Stretch.

Ordinal Scale for Evaluation of Pliability

Figure 5.2-9a. 0 = Very soft handle with lofty fibres, stretch in all directions and a limp drape. Bends in two dimensions and forms folds. Similar in drape to a medium weight T-shirt.

Figure 5.2-9b (above left). 1 = Soft handle with moderate loft and stretch, and soft drape. Bends in two dimensions and form open undulations as opposed to folds. Similar in drape to a heavy flannel shirt.

Figure 5.2-9c (above right). 2 = Pliable but with less loft, some stretch and a moderate drape. Forms a narrow U shape and bends primarily in one direction. Similar in drape to classic blue jean fabric.

Figure 5.2-9d. 3 = Flexible but with little loft, little to no stretch, a stiff drape and in some cases a papery sound when rustled. Forms an open U shape and has only unidirectional bend. Similar in drape to medium duck canvas.

Figure 5.2-9e. 4 = Moderate bendability with no loft, no stretch, a stiff drape and in some cases a cardboard sound when flexed. Forms a very open rounded U shape and has only unidirectional bend. Similar in drape to very heavy canvas.

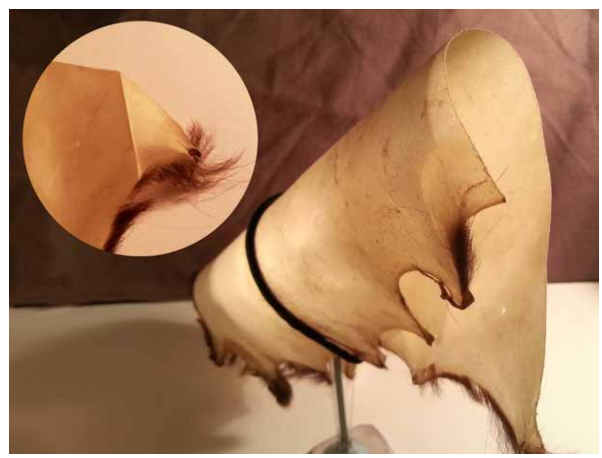


Figure 5.2-9f. 5 = Hard, cracks or splits when bent or permanently creases, no drape. Similar to the feel of post card paper. Inset illustrates a permanent crease.

Figure 5.2-9g. 6 = Very hard, no bendability but may flex slightly. A feel equivalent to a piece of 1/4 inch (4mm) plywood.

Light Translucence and UV Reactivity Tables

Species	Hair	Light Translucence	UV Reaction	UV Reaction Fresh cut	Miscellaneous
American Badger *Taxidea taxus*	On	Yes	Strong	Strong	
Beaver *Castor Canadensis*	On	Yes	Strong	Strong	
American Bison *Bison bison*	On	Yes- in dim light	Strong	Strong	Thin interior strip glows yellow-green not white under UV
American Bison *Bison bison*	Off	Yes- In dark only	Strong	Strong	
Big Horn Sheep *Ovis Canadensis*	Off	Yes	Strong	Strong	
Black Bear *Ursus americanus*	On	Yes	Strong	Strong	
Canadian Lynx *Lynx canadensis*	On	Yes	Strong	Strong	
American Elk *Cervus Canadensis*	Off	Yes	Strong	Strong	
Exmoor Pony *Equus ferus caballus*	Off	Yes	Strong	Strong	
Fallow Deer *Dama dama*	Off	Yes	Strong	Strong	Scars glow more strongly under UV than normal tissue
Galloway Cow *Bos taurus*	Off	Yes- In dim light	Strong	Strong	
German Shepherd *Canis lupus familiaris*	On	Yes	Strong	Strong	
Moose *Alces alces*	Off	Yes -In dark only	Strong	Strong	
Mule Deer *Odocoileus virginianus*	Off	Yes	Strong	Strong	
Pronghorn Antelope *Antilocapra americana*	Off	Yes	Strong	Strong	
Rabbit *Sylvilagus sp*	On	Yes	Strong	Strong	
Red Deer *Cervus elaphus*	Off	Yes	Strong	Strong	
Red Fox *Vulpes vulpes*	On	Yes	Strong	Strong	
Reindeer/Caribou *Rangifer tarandus*	On	Yes	Strong	Strong	
Reindeer/Caribou *Rangifer tarandus*	Off	Yes	Strong	Strong	
Roe Deer *Capreolus capreolus*	Off	Yes	Strong	Strong	
Soay Sheep *Ovis aries*	On	Yes	Strong	Strong	
Soay Sheep *Ovis aries*	Off	Yes	Strong	Strong	
Toggenburg Goat *Capra aegagrus hircus*	On	Yes	Strong	Strong	
Toggenburg Goat *Capra aegagrus hircus*	Off	Yes – In dim light	Strong	Strong	

Figure 5.2-10. Alum Taw Light Translucence and UV Reactivity.

Species	Hair	Light Translucence	UV Reaction	UV Reaction Fresh cut	Miscellaneous
American Badger *Taxidea taxus*	On	No	None	Interior	
Beaver *Castor Canadensis*	On	No	None	No	Epidermis fluoresces
American Bison *Bison bison*	On	No	None	Interior	Very thick interior stripe
American Bison *Bison bison*	Off	No	None	Interior	
Big Horn Sheep *Ovis Canadensis*	Off	No	None	Interior	Hair roots and shafts fluoresce
Black Bear *Ursus americanus*	On	No	None	None	
Canadian Lynx *Lynx canadensis*	On	No	None	None	
American Elk *Cervus Canadensis*	Off	No	None	None	
Exmoor Pony *Equus ferus caballus*	Off	No	None	None	
Fallow Deer *Dama dama*	Off	No	None	None	
Galloway Cow *Bos taurus*	Off	No	None	None	Lack of UV reaction surprising as compacted fibres can be seen and felt
German Shepherd *Canis lupus familiaris*	On	No	None	None	
Moose *Alces alces*	Off	No	None	None	
Mule Deer *Odocoileus virginianus*	Off	No	None	None	
Pronghorn Antelope *Antilocapra americana*	Off	No	None	None	
Rabbit *Sylvilagus sp*	On	Yes	None	None	Some very minimal light translucence in complete darkness.
Red Deer *Cervus elaphus*	Off	No	None	None	Hair roots fluoresce
Red Fox *Vulpes vulpes*	On	No	None	None	
Reindeer/Caribou *Rangifer tarandus*	On	No	None	None	
Reindeer/Caribou *Rangifer tarandus*	Off	No	None	None	
Roe Deer *Capreolus capreolus*	Off	No	None	None	
Soay Sheep *Ovis aries*	On	No	None	None	
Soay Sheep *Ovis aries*	Off	No	None	None	
Toggenburg Goat *Capra aegagrus hircus*	On	No	None	None	
Toggenburg Goat *Capra aegagrus hircus*	Off	No	None	Interior	Very thin interior strip under UV
Wild Boar *Sus scrofa*	Off	No	None	Interior	Weak interior UV reaction

Figure 5.2-11. Vegetable Tan Light Translucence and UV Reactivity.

Species	Hair	Light Translucence	UV Reaction	UV Reaction Fresh cut	Miscellaneous
American Badger *Taxidea taxus*	On	Yes	Moderate	Strong	
Beaver *Castor Canadensis*	On	Yes	Moderate	Strong	
American Bison *Bison bison*	On	Yes	Moderate	Strong	
American Bison *Bison bison*	Off	Yes	Moderate	Strong	
Big Horn Sheep *Ovis Canadensis*	Off	Yes	Strong	Strong	
Black Bear *Ursus americanus*	On	Yes	Moderate	Strong	
Canadian Lynx *Lynx canadensis*	On	No Samp.	No Samp.	No Samp.	
American Elk *Cervus Canadensis*	Off	Yes	Strong	Strong	
Exmoor Pony *Equus ferus caballus*	Off	Yes	Moderate	Strong	Grain and membrane remnants fluoresce more strongly than dermis.
Fallow Deer *Dama dama*	Off	Yes	Moderate	Strong	Light translucence only visible in dark conditions.
Galloway Cow *Bos taurus*	Off	Yes	Moderate	Strong	
German Shepherd *Canis lupus familiaris*	On	Yes	Moderate	Strong	Interior stripe fluoresces more strongly that surrounding dermis.
Moose *Alces alces*	Off	Yes	Moderate	Strong	
Mule Deer *Odocoileus virginianus*	Off	Yes	Moderate	Strong	
Pronghorn Antelope *Antilocapra americana*	Off		Moderate	Strong	
Rabbit *Sylvilagus sp*	On	Yes	Moderate	Strong	
Red Deer *Cervus elaphus*	Off	Yes	Moderate	Strong	
Red Fox *Vulpes vulpes*	On	No Samp.	No Samp.	No Samp.	
Reindeer/Caribou *Rangifer tarandus*	On	Yes	Moderate	Strong	
Reindeer/Caribou *Rangifer tarandus*	Off	Yes	Moderate	Moderate	
Roe Deer *Capreolus capreolus*	Off	Yes	Moderate	Strong	
Soay Sheep *Ovis aries*	On	Yes	Moderate	Strong	
Soay Sheep *Ovis aries*	Off	Yes	Moderate	Strong	
Toggenburg Goat *Capra aegagrus hircus*	On	Yes	Moderate	Moderate	
Toggenburg Goat *Capra aegagrus hircus*	Off	Yes	Moderate	Strong	Very strong UV reaction

Figure 5.2-12. Dry Scrape Brain Tan Light Translucence and UV Reactivity.

Species	Hair	Light Translucence	UV Reaction	UV Reaction Fresh cut	Miscellaneous
American Badger *Taxidea taxus*	On	Yes	Moderate	Strong	
Beaver *Castor Canadensis*	On	Yes	Moderate	Strong	
American Bison *Bison bison*	On	Yes	Moderate	Strong	Light shines visible only in darkened conditions
American Bison *Bison bison*	Off	Yes	Moderate	Strong	
Big Horn Sheep *Ovis Canadensis*	Off	Yes	Strong	Strong	Grain remnants fluoresce more strongly than surrounding dermis.
Black Bear *Ursus americanus*	On	Yes	Moderate	Strong	
Canadian Lynx *Lynx canadensis*	On	Yes	Moderate	Strong	
American Elk *Cervus Canadensis*	Off	Yes	Moderate	Strong	
Exmoor Pony *Equus ferus caballus*	Off	Yes	Strong	Strong	Grain remnants fluoresce more strongly than surrounding dermis.
Fallow Deer *Dama dama*	Off	No Sample			
Galloway Cow *Bos taurus*	Off	Yes	Moderate	Strong	
German Shepherd *Canis lupus familiaris*	On	Yes	Moderate	Strong	
Moose *Alces alces*	Off	Yes	Moderate	Strong	
Mule Deer *Odocoileus virginianus*	Off	Yes	Moderate	Strong	
Pronghorn Antelope *Antilocapra americana*	Off	Yes	Moderate	Strong	
Rabbit *Sylvilagus sp*	On	Yes	Moderate	Strong	Scar tissue fluoresces more strongly than surrounding dermis.
Red Deer *Cervus elaphus*	Off	Yes	Moderate	Strong	
Red Fox *Vulpes vulpes*	On	Yes	Moderate	Strong	
Reindeer/Caribou *Rangifer tarandus*	On	Yes	Moderate	Strong	
Reindeer/Caribou *Rangifer tarandus*	Off	Yes	Moderate	Strong	
Roe Deer *Capreolus capreolus*	Off	Yes	Moderate	Strong	
Soay Sheep *Ovis aries*	On	Yes	Moderate	Strong	
Soay Sheep *Ovis aries*	Off	Yes	Moderate	Strong	
Toggenburg Goat *Capra aegagrus hircus*	On	No Sample			
Toggenburg Goat *Capra aegagrus hircus*	Off	Yes	Moderate	Strong	

Figure 5.2-13. Wet Scrape Brain Tan Light Translucence and UV Reactivity.

Species	Hair	Light Translucence	UV Reaction	UV Reaction Fresh cut	Miscellaneous
American Badger *Taxidea taxus*	On	Yes	Strong	Strong	
Beaver *Castor Canadensis*	On	Yes	Strong	Strong	
American Bison *Bison bison*	On	No Sample			
American Bison *Bison bison*	Off	Yes	Strong	Strong	
Big Horn Sheep *Ovis Canadensis*	Off	Yes	Strong	Strong	
Black Bear *Ursus americanus*	On	Yes	Strong	Strong	
Canadian Lynx *Lynx canadensis*	On	Yes	Strong	Strong	
American Elk *Cervus Canadensis*	Off	Yes	Strong	Strong	
Exmoor Pony *Equus ferus caballus*	Off	Yes	Strong	Strong	
Fallow Deer *Dama dama*	Off	Yes	Strong	Strong	
Galloway Cow *Bos taurus*	Off	Yes	Strong	Strong	
German Shepherd *Canis lupus familiaris*	On	Yes	Strong	Strong	
Moose *Alces alces*	Off	Yes	Strong	Strong	
Mule Deer *Odocoileus virginianus*	Off	Yes	Strong	Strong	
Pronghorn Antelope *Antilocapra americana*	Off	Yes	Strong	Strong	
Rabbit *Sylvilagus sp*	On	Yes	Strong	Strong	
Red Deer *Cervus elaphus*	Off	Yes	Strong	Strong	
Red Fox *Vulpes vulpes*	On	Yes	Strong	Strong	
Reindeer/Caribou *Rangifer tarandus*	On	Yes	Strong	Strong	
Reindeer/Caribou *Rangifer tarandus*	Off	Yes	Strong	Strong	
Roe Deer *Capreolus capreolus*	Off	Yes	Strong	Strong	
Soay Sheep *Ovis aries*	On	Yes	Strong	Strong	
Soay Sheep *Ovis aries*	Off	Yes	Strong	Strong	Epidermis fluoresces weakly and flesh side is dull (dirty?)
Toggenburg Goat *Capra aegagrus hircus*	On	No Sample			
Toggenburg Goat *Capra aegagrus hircus*	Off	Yes	Strong	Strong	

Figure 5.2-14. Urine Tan Light Translucence and UV Reactivity.

Species	Hair	Light Translucence	UV Reaction	UV Reaction Fresh cut	Miscellaneous
American Badger *Taxidea taxus*	On	Yes	Strong	Strong	
Beaver *Castor Canadensis*	On	Yes	Strong	Strong	
American Bison *Bison bison*	On	Yes	Strong	Strong	
American Bison *Bison bison*	Off	Yes	Strong	Strong	
Big Horn Sheep *Ovis Canadensis*	Off	Yes	Strong	Strong	
Black Bear *Ursus americanus*	On	Yes	Strong	Strong	
Canadian Lynx *Lynx canadensis*	On	Yes	Strong	Strong	
American Elk *Cervus Canadensis*	Off	Yes	Strong	Strong	
Exmoor Pony *Equus ferus caballus*	Off	Yes	Strong	Strong	Mane stripe .6 – .8 mm thick
Fallow Deer *Dama dama*	Off	Yes	Strong	Strong	
Galloway Cow *Bos taurus*	Off	Yes	Strong	Strong	
German Shepherd *Canis lupus familiaris*	On	Yes	Strong	Strong	
Moose *Alces alces*	Off	Yes	Strong	Strong	
Mule Deer *Odocoileus virginianus*	Off	Yes	Strong	Strong	
Pronghorn Antelope *Antilocapra americana*	Off	Yes	Strong	Strong	
Rabbit *Sylvilagus sp*	On	Yes	Strong	Strong	
Red Deer *Cervus elaphus*	Off	Yes	Strong	Strong	
Red Fox *Vulpes vulpes*	On	Yes	Strong	Strong	
Reindeer/Caribou *Rangifer tarandus*	On	Yes	Strong	Strong	
Reindeer/Caribou *Rangifer tarandus*	Off	Yes	Strong	Strong	
Roe Deer *Capreolus capreolus*	Off	Yes	Strong	Strong	
Soay Sheep *Ovis aries*	On	Yes	Strong	Strong	
Soay Sheep *Ovis aries*	Off	Yes	Strong	Strong	
Toggenburg Goat *Capra aegagrus hircus*	On	Yes	Strong	Strong	
Toggenburg Goat *Capra aegagrus hircus*	Off	Yes	Strong	Strong	

Figure 5.2-15. Rawhide Light Translucence and UV Reactivity.

Macroscopic Analysis Criteria Tables

Species	Hair	Colour Flesh Side	Colour Grain Side	Pliability	Stretch	Surface Texture Grain Side	Surface Texture Flesh Side	Membrane Remnants	Fibre Rolls	Miscellaneous
American Badger *Taxidea taxus*	On	Cream	Fur	3	2	Fur	Rough and Scratchy	No	Yes	Hair pull through
Beaver *Castor Canadensis*	On	Cream	Fur	2	2	Fur	Rough and Scratchy	No	Yes	
American Bison *Bison bison*	On	Cream	Cream	3	2	Heavily Textured	Coarsely Fuzzy	No	Yes	Pink mildew stains
American Bison *Bison bison*	Off	Grey-Yellow cast	Fur- Dark Brown	4	3	Fur	Lightly Fuzzy	No	Yes	
Big Horn Sheep *Ovis Canadensis*	Off	Cream	White	1	0	Slightly Textured	Coarsely Fuzzy	No	Yes	
Black Bear *Ursus americanus*	On	Cream	Fur	3	3	Fur	Rough and Scratchy	No	Yes	
Canadian Lynx *Lynx canadensis*	On	Cream	Fur	2	1	Fur	Slightly Rough and Scratchy	No	Yes	
American Elk *Cervus Canadensis*	Off	Cream	Cream-Tan Spots	2	1	Heavily Textured with Hard Spots	Lightly Fuzzy	No	Yes	
Exmoor Pony *Equus ferus caballus*	Off	Yellow Cast	White	1	0	Slightly Textured	Coarsely Fuzzy	No	Yes	
Fallow Deer *Dama dama*	Off	Cream	White	1	0	Smooth with Slightly Text. Spots	Lightly Fuzzy	No	Yes	
Galloway Cow *Bos taurus*	Off	Cream	Cream	4	3	Heavily Textured	Coarsely Fuzzy	No	Yes	
German Sheppard *Canis lupus familiaris*	On	Cream	Fur	1	1	Fur	Slightly Rough and Scratchy	No	No	Hair pull through
Moose *Alces alces*	Off	Cream	Cream-Tan Spots	2	1	Heavily Textured	Coarsely Fuzzy	No	Yes	Many small hard spots
Mule Deer *Odocoileus virginianus*	Off	Cream	White	0	0	Slightly Textured	Very Lightly Fuzzy	No	Yes	Super stretch, limp drape
Pronghorn Antelope *Antilocapra americana*	Off	Cream	Cream	0	0	Lightly Rough and Scratchy	Very Lightly Fuzzy	No	Yes	No grain
Rabbit *Sylvilagus sp*	On	Yellow Cast	White	2	1	Fur	Lightly Fuzzy	Yes	Yes	Some fur slippage
Red Deer *Cervus elaphus*	Off	Yellow Cast	White	1	0	Moderately Textured	Coarsely Fuzzy	No	Yes	
Red Fox *Vulpes vulpes*	On	Cream	Fur	0	0	Fur	Slightly Rough and Scratchy	No	No	
Reindeer/Caribou *Rangifer tarandus*	On	Cream	Fur	2	1	Fur	Lightly Fuzzy	Yes	Yes	
Reindeer/Caribou *Rangifer tarandus*	Off	Cream	Cream	1	1	Slightly Textured	Lightly Fuzzy	Yes	Yes	
Roe Deer *Capreolus capreolus*	Off	Yellow Cast	White	1	0	Slightly Textured	Slightly Rough and Scratchy	No	Yes	Eggs coloured the flesh side slightly
Soay Sheep *Ovis aries*	On	Cream	Fur	1	1	Fur	Very Lightly Fuzzy	No	Yes	
Soay Sheep *Ovis aries*	Off	Cream	White	1	0	Smooth	Very Lightly Fuzzy	No	Yes	
Toggenburg Goat *Capra aegagrus hircus*	On	White	Fur	2	2	Fur	Lightly Fuzzy	No	Yes	
Toggenburg Goat *Capra aegagrus hircus*	Off	Cream	Cream-Yellow Cast	2	2	Slightly Textured, Rough Scratchy	Slightly Rough and Scratchy	No	Yes	Grain broken in some areas

Figure 5.2-16. Alum Taw Macroscopic Analysis Criteria.

Species	Hair	Colour Flesh Side	Colour Grain Side	Pliability	Stretch	Surface Texture Grain Side	Surface Texture Flesh Side	Membrane Remnants	Fibre Rolls	Miscellaneous
American Badger *Taxidea taxus*	On	Red Brown	Fur	2	2	Fur	Slightly Rough and Scratchy	No	Yes	Hair pull through
Beaver *Castor Canadensis*	On	Red Brown	Red Brown	2	1	Fur	Coarsely Fuzzy	No	Yes	Some hair slippage
American Bison *Bison bison*	On	Dark Brown	Fur	4	3	Fur	Lightly Fuzzy	No	Yes	
American Bison *Bison bison*	Off	Dark Brown	Dark Brown	4	3	Heavily Textured	Coarsely Fuzzy	No	Yes	
Big Horn Sheep *Ovis Canadensis*	Off	Red Brown	Red Brown	2	2	Slightly Textured	Lightly Fuzzy	No	Yes	
Black Bear *Ursus americanus*	On	Red Brown	Red Brown	2	2	Fur	Coarsely Fuzzy	No	Yes	
Canadian Lynx *Lynx canadensis*	On	Red Brown	Fur	2	1	Fur	Coarsely Fuzzy	No	Yes	
American Elk *Cervus Canadensis*	Off	Light Brown	Red Brown	3	2	Heavily Textured	Lightly Fuzzy	No	Yes	
Exmoor Pony *Equus ferus caballus*	Off	Light Brown	Red Brown	2	1	Smooth	Very Lightly Fuzzy	No	Yes	
Fallow Deer *Dama dama*	Off	Red Brown	Red Brown	2	2	Slightly Textured	Lightly Fuzzy	No	Yes	
Galloway Cow *Bos taurus*	Off	Light Brown	Dark Brown	4	3	Heavily Textured	Lightly Fuzzy	No	Yes	
German Sheppard *Canis lupus familiaris*	On	Light Brown	Fur	1	0	Fur	Slightly Rough and Scratchy	No	Yes	Hair pull through, Some hair slippage
Moose *Alces alces*	Off	Light Brown	Red Brown/ Dark spots	3	3	Heavily Textured	Coarsely Fuzzy	No	Yes	
Mule Deer *Odocoileus virginianus*	Off	Light Brown	Light Brown/ Dark Spots	1	1	Smooth	Lightly Fuzzy	No	Yes	
Pronghorn Antelope *Antilocapra americana*	Off	Light Brown	Light Brown	0	0	Lightly Rough and Scratchy	Very Lightly Fuzzy	No	Yes	No grain layer
Rabbit *Sylvilagus sp*	On	Red Brown	Fur	2	2	Fur	Lightly Fuzzy	Yes	Yes	Some hair slippage
Red Deer *Cervus elaphus*	Off	Light Brown	Red Brown	2	1	Heavily Textured	Coarsely Fuzzy	No	Yes	
Red Fox *Vulpes vulpes*	On	Red Brown	Fur	1	1	Fur	Very Lightly Fuzzy	No	No	
Reindeer/Caribou *Rangifer tarandus*	On	Light Brown	Fur	2	2	Fur	Very Lightly Fuzzy	Yes	No	
Reindeer/Caribou *Rangifer tarandus*	Off	Light Brown	Red Brown	2	2	Moderately Textured	Very Lightly Fuzzy	Yes	No	
Roe Deer *Capreolus capreolus*	Off	Light Brown	Light Brown	2	2	Smooth	Very Lightly Fuzzy	No	Yes	
Soay Sheep *Ovis aries*	On	Light Brown	Fur	2	2	Fur	Very Lightly Fuzzy	No	No	
Soay Sheep *Ovis aries*	Off	Light Brown	Light Brown	2	1	Slightly Textured	Very Lightly Fuzzy	No	No	
Toggenburg Goat *Capra aegagrus hircus*	On	Red Brown	Fur	2	2	Fur	Coarsely Fuzzy	No	Yes	
Toggenburg Goat *Capra aegagrus hircus*	Off	Red Brown	Dark Brown	2	2	Slightly Textured	Very Lightly Fuzzy	No	No	
Wild Boar *Sus scrofa*	Off	Grey Brown	Brown	4	3	Heavily Textured	Heavily Textured	No	No	

Figure 5.2-17. Vegetable Tan Macroscopic Analysis Criteria.

Species	Hair on or off	Colour Flesh Side	Pliability	Stretch	Surface Texture Grain Side	Surface Texture Flesh Side	Membrane Remnants	Fibre Rolls	Miscellaneous
American Badger *Taxidea taxus*	On	Golden Tan	2	2	Fur	Rough and Scratchy	No	Yes	Hair pull through
Beaver *Castor Canadensis*	On	Golden Tan	1	2	Fur	Coarsely Fuzzy	No	Yes	
American Bison *Bison bison*	On	Grey Tan	2	2	Fur	Coarsely Fuzzy	Yes	Yes	
American Bison *Bison bison*	Off	Golden Tan	2	2	Coarsely Fuzzy	Coarsely Fuzzy	No	Yes	Thin cemented middle strip
Big Horn Sheep *Ovis Canadensis*	Off	Cream	0	1	Lightly Fuzzy	Lightly Fuzzy	No	Yes	Unsmoked, slightly sour smell
Black Bear *Ursus americanus*	On	Golden Tan	2	2	Fur	Slightly Rough and Scratchy	No	Yes	
Canadian Lynx *Lynx canadensis*	On	Light Golden Tan	1	2	Fur	Very Lightly Fuzzy	Yes	Yes	Hair pull through
American Elk *Cervus Canadensis*	Off	Golden Tan	0	0	Lightly Fuzzy	Coarsely Fuzzy	No	Yes	
Exmoor Pony *Equus ferus caballus*	Off	Light Golden Tan	0	0	Smooth	Lightly Fuzzy	No	Yes	Grain still partially intact
Galloway Cow *Bos taurus*	Off	Grey Tan	4	3	Lightly Fuzzy	Coarsely Fuzzy	Yes	Yes	Thin cemented middle strip
German Sheppard *Canis lupus familiaris*	On	Golden Tan	0	0	Fur	Lightly Fuzzy	No	Yes	Very stretchy pelt, hair pull through
Moose *Alces alces*	Off	Golden Tan	1	1	Lightly Fuzzy	Coarsely Fuzzy	No	Yes	Very thin cement-ed middle strip
Mule Deer *Odocoileus virginianus*	Off	Golden Tan	0	0	Very Lightly Fuzzy	Coarsely Fuzzy	No	Yes	
Pronghorn Antelope *Antilocapra americana*	Off	Golden Tan	0	0	Very Lightly Fuzzy	Lightly Fuzzy	Yes	Yes	
Rabbit *Sylvilagus sp*	On	Light Golden Tan	2	2	Fur	Very Lightly Fuzzy	No	Yes	Slippage
Red Deer *Cervus elaphus*	Off	Golden Tan	0	0	Lightly Fuzzy	Coarsely Fuzzy	Yes	Yes	Very soft
Red Fox *Vulpes vulpes*	On	Golden Tan	0	0	Fur	Very Lightly Fuzzy	No	Yes	
Reindeer/Caribou *Rangifer tarandus*	On				Fur				
Reindeer/Caribou *Rangifer tarandus*	Off	Golden Tan	1	0	Very Lightly Fuzzy	Lightly Fuzzy	Yes	Yes	
Roe Deer *Capreolus capreolus*	Off	Golden Tan	0	0	Very Lightly Fuzzy	Very Lightly Fuzzy	Yes	Yes	
Soay Sheep *Ovis aries*	On	Light Golden Tan	2	1	Fur	Lightly Fuzzy	No	Yes	
Soay Sheep *Ovis aries*	Off	Golden Tan	0	0	Very Lightly Fuzzy	Very Lightly Fuzzy	No	No	
Toggenburg Goat *Capra aegagrus hircus*	Off	Golden Tan	0	0	Lightly Fuzzy	Lightly Fuzzy	No	No	

Figure 5.2-18. Wet Scrape Brain Tan Macroscopic Analysis Criteria.

Species	Hair on or off	Colour Flesh Side	Pliability	Stretch	Surface Texture Grain Side	Surface Texture Flesh Side	Membrane Remnants	Fibre Rolls	Miscellaneous
American Badger *Taxidea taxus*	On	Light Golden Tan	2	2	Fur	Slightly Rough and Scratchy	No	Yes	Hair root pull through
Beaver *Castor Canadensis*	On	Light Golden Tan	1	2	Fur	Lightly Fuzzy	No	Yes	
American Bison *Bison bison*	On	Grey Tan	3	3	Fur	Coarsely Fuzzy	No	Yes	Light translucence only visible in dark conditions.
American Bison *Bison bison*	Off	Golden Tan	2	2	Coarsely Fuzzy	Coarsely Fuzzy	No	Yes	Stringy fibres Grain Side, Very thin cemented strip.
Big Horn Sheep *Ovis Canadensis*	Off	Cream	1	1	Lightly Fuzzy	Coarsely Fuzzy	No	Yes	Unsmoked/ sour smell
Black Bear *Ursus americanus*	On	Golden Tan	3	3	Fur	Slightly Rough and Scratchy	No	Yes	Hair root pull through
American Elk *Cervus Canadensis*	Off	Golden Tan	1	1	Lightly Fuzzy	Lightly Fuzzy	No	Yes	
Exmoor Pony *Equus ferus caballus*	Off	Golden Tan	2	1	Very Lightly Fuzzy	Lightly Fuzzy	No	Yes	
Fallow Deer *Dama dama*	On	Cream	2	1	Very Lightly Fuzzy	Lightly Fuzzy	Yes	Yes	Some rough patches Flesh side, Unsmoked,
Galloway Cow *Bos taurus*	Off	Light Golden Tan	4	3	Coarsely Fuzzy	Lightly Fuzzy	No	Yes	
German Sheppard *Canis lupus familiaris*	On	Light Golden Tan	1	1	Fur	Lightly Fuzzy	No	No	Some hair pull through
Moose *Alces alces*	Off	Golden Tan	2	2	Lightly Fuzzy	Coarsely Fuzzy	Yes	Yes	
Mule Deer *Odocoileus virginianus*	Off	Golden Tan	0	0	Very Lightly Fuzzy	Lightly Fuzzy	Yes	No	Super soft
Pronghorn Antelope *Antilocapra americana*	Off	Golden Tan	1	1	Very Lightly Fuzzy	Coarsely Fuzzy	No	Yes	
Rabbit *Sylvilagus sp*	On	Light Golden Tan	2	2	Fur	Coarsely Fuzzy	No	Yes	Very old animal
Red Deer *Cervus elaphus*	Off	Golden Tan	0	0	Slightly Rough and Scratchy	Coarsely Fuzzy	Yes	Yes	Grain side slightly rough/scratchy
Red Fox *Vulpes vulpes*	On	Light Golden Tan	1	2	Fur	Lightly Fuzzy	No	Yes	
Reindeer/Caribou *Rangifer tarandus*	On	Golden Tan	2	2	Fur	Lightly Fuzzy	Yes	Yes	
Reindeer/Caribou *Rangifer tarandus*	Off	Golden Tan	1	0	Very Lightly Fuzzy	Very Lightly Fuzzy	Yes	Yes	
Roe Deer *Capreolus capreolus*	Off	Golden Tan	0	0	Very Lightly Fuzzy	Lightly Fuzzy	Yes	Yes	
Soay Sheep *Ovis aries*	On	Light Golden Tan	2	1	Fur	Lightly Fuzzy	No	Yes	
Soay Sheep *Ovis aries*	Off	Golden Tan	1	1	Lightly Rough and Scratchy	Very Lightly Fuzzy	No	Yes	
Toggenburg Goat *Capra aegagrus hircus*	On	Light Golden Tan	3	3	Fur	Lightly Fuzzy	No	No	Still smells of goat!
Toggenburg Goat *Capra aegagrus hircus*	Off	Golden Tan	0	0	Lightly Fuzzy	Lightly Fuzzy	No	Yes	
Wild Boar *Sus scrofa*	Off	Golden Tan	4	3	Rough and Scratchy	Very Lightly Fuzzy	No	No	No cracking or splitting

Figure 5.2-19. Dry Scrape Brain Tan Macroscopic Analysis Criteria.

Species	Hair on or off	Colour Flesh Side	Colour Grain Side	Pliability	Stretch	Surface Texture Grain Side	Surface Texture Flesh Side	Membrane Remnants	Fibre Rolls	Miscellaneous
American Badger *Taxidea taxus*	On	Yellow	Fur	2	2	Fur	Slightly Rough and Scratchy	No	Yes	Hair pull through
Beaver *Castor Canadensis*	On	Cream	Fur	1	2	Fur	Coarsely Fuzzy	No	Yes	
American Bison *Bison bison*	Off	Yellow	Yellow	2	2	Heavily Textured	Coarsely Fuzzy	No	Yes	
Big Horn Sheep *Ovis Canadensis*	Off	Cream	Yellow with brown spots	1	1	Slightly Textured	Lightly Fuzzy	Yes	Yes	bruising has dis-coloured the sample
Black Bear *Ursus americanus*	On	Cream	Fur	3	3	Fur	Coarsely Fuzzy	No	Yes	Hair pull through
Canadian Lynx *Lynx canadensis*	On	Cream	Fur	0	0	Fur	Lightly Fuzzy	No	Yes	
American Elk *Cervus Canadensis*	Off	Cream	Cream	2	2	Heavily Textured	Very Lightly Fuzzy	Yes	Yes	Flesh side oddly smooth for Elk
Exmoor Pony *Equus ferus caballus*	Off	Cream	Yellow	1	1	Smooth	Very Lightly Fuzzy	No	Yes	Flesh side has crosshatch fibres
Fallow Deer *Dama dama*	Off	Cream	Yellow	2	2	Slightly Textured	Lightly Fuzzy	No	Yes	
Galloway Cow *Bos taurus*	Off	Cream	Cream	4	3	Slightly Textured	Coarsely Fuzzy	No	Yes	
German Sheppard *Canis lupus familiaris*	On	Cream	Fur	1	1	Fur	Slightly Rough and Scratchy	No	Yes	Hair pull through
Moose *Alces alces*	Off	Cream	Cream with brown spots	3	3	Slightly Textured	Coarsely Fuzzy	No	Yes	
Mule Deer *Odocoileus virginianus*	Off	Cream	Yellow	0	0	Slightly Textured	Very Lightly Fuzzy	No	No	Very soft/stretchy for UT Grain on
Pronghorn Antelope *Antilocapra americana*	Off	Cream	Cream	0	0	Lightly Rough and Scratchy	Very Lightly Fuzzy	No	Yes	no grain
Rabbit *Sylvilagus sp*	On	Cream	Fur	3	3	Fur	Very Lightly Fuzzy	Yes	Yes	fur slippage
Red Deer *Cervus elaphus*	Off	Cream	Yellow	1	1	Heavily Textured	Coarsely Fuzzy	Yes	Yes	
Red Fox *Vulpes vulpes*	On	Yellow	Fur	1	0	Fur	Lightly Fuzzy	No	Yes	
Reindeer/Caribou *Rangifer tarandus*	Off	Cream	Yellow	2	1	Slightly Textured	Lightly Fuzzy	Yes	Yes	
Roe Deer *Capreolus capreolus*	Off	Cream	Cream	1	1	Slightly Textured	Lightly Fuzzy	Yes	Yes	some grain separation
Soay Sheep *Ovis aries*	On	Yellow	Fur	2	2	Fur	Lightly Fuzzy	No	Yes	
Soay Sheep *Ovis aries*	Off	Cream	Yellow/ Grey	1	1	Smooth	Smooth	No	No	
Toggenburg Goat *Capra aegagrus hircus*	On	Cream	Fur	4	3	Fur	Coarsely Fuzzy	No	Yes	grain separation, fur slip, goat smell
Toggenburg Goat *Capra aegagrus hircus*	Off	Cream	Cream	2	2	Slightly Textured	Lightly Fuzzy	No	Yes	grain separation

Figure 5.2-20. Urine Tan Macroscopic Analysis Criteria.

Species	Hair on or off	Colour Flesh Side	Colour Grain Side	Pliability	Stretch	Surface Texture Grain Side	Surface Texture Flesh Side	Membrane Remnants	Fibre Rolls	Miscellaneous
American Badger *Taxidea taxus*	On	Cream and Yellow	Fur	5	3	Fur	Slightly Rough and Scratchy – Greasy	Yes	Yes	
Beaver *Castor Canadensis*	On	Cream and Transparent	Fur	5	3	Fur	Slightly Rough and Scratchy	Yes	No	
American Bison *Bison bison*	On	Cream and Yellow	Fur	6	3	Fur	Lightly Fuzzy	No	No	
American Bison *Bison bison*	Off	Yellow	Yellow	6	3	Smooth	Slightly Rough and Scratchy	Yes	No	Slightly cross hatched appearance to Flesh Side. Grain thin in comparison to dermis.
Big Horn Sheep *Ovis Canadensis*	Off	Yellow	Yellow	5	3	Smooth	Slightly Rough and Scratchy	Yes	No	
Black Bear *Ursus americanus*	On	Cream and Transparent	Fur	5	3	Fur	Rough and Scratchy	Yes	No	
Canadian Lynx *Lynx canadensis*	On	Yellow	Fur	4	3	Fur	Smooth	Yes	No	Pliability due to exceptional thinness. Hair roots visible through dermis.
American Elk *Cervus Canadensis*	Off	Cream	Yellow and Transparent	5	3	Smooth / Slightly Textured	Slightly Rough and Scratchy	Yes	No	
Exmoor Pony *Equus ferus caballus*	Off	Cream and Yellow	Cream and Yellow	5	3	Very Smooth	Slightly Rough and Scratchy	Yes	No	
Fallow Deer *Dama dama*	Off	Cream and Transparent	Cream and Transparent	5	3	Very Smooth	Slightly Rough and Scratchy	Yes	No	
Galloway Cow *Bos taurus*	Off	Transparent	Transparent	6	3	Slightly Textured	Slightly Rough and Scratchy	Yes	No	
German Sheppard *Canis lupus familiaris*	On	Cream	Fur	5	3	Fur	Rough and Scratchy	Yes	Yes	Hair pull through
Moose *Alces alces*	Off	Light Brown Transparent	Light Brown Transparent	6	3	Slightly Textured	Slightly Textured	Yes	No	Photographed very well
Mule Deer *Odocoileus virginianus*	Off	Cream and Transparent	Yellow	5	3	Smooth	Slightly Rough and Scratchy	No	No	
Pronghorn Antelope *Antilocapra americana*	Off	Cream and Transparent	Cream and Transparent	5	3	Smooth	Slightly Rough and Scratchy	Yes	No	Either visible hair roots or melanin remnants.
Rabbit *Sylvilagus sp*	On	Cream and Transparent	Fur	5	3	Fur	Slightly Textured	Yes	No	Visible stretch lines and direction of hair growth.
Red Deer *Cervus elaphus*	Off	Cream and Transparent	Cream and Transparent	5	3	Slightly Textured	Slightly Textured	Yes	No	
Red Fox *Vulpes vulpes*	On	Cream	Fur	4	3	Fur	Slightly Textured – Greasy	Yes	No	Very thin
Reindeer/Caribou *Rangifer tarandus*	On	Cream and Transparent	Fur	5	3	Fur	Smooth	Yes	No	
Reindeer/Caribou *Rangifer tarandus*	Off	Yellow and Transparent	Yellow and Transparent	5	3	Smooth	Slightly Textured	Yes	No	
Roe Deer *Capreolus capreolus*	Off	Cream and Transparent	Cream and Transparent	5	3	Slightly Textured	Smooth	Yes	No	
Soay Sheep *Ovis aries*	On	Hair-on	Dark Brown	5	3	Fur	Smooth	No	No	
Soay Sheep *Ovis aries*	Off	White and Translucent	Light Brown and Translucent	5	3	Smooth	Slightly Textured	Yes	No	
Toggenburg Goat *Capra aegagrus hircus*	On	Light Brown Transparent	Fur	5	3	Fur	Slightly Rough and Scratchy – Greasy	Yes	No	Fat pockets remaining, Smells of goat
Toggenburg Goat *Capra aegagrus hircus*	Off	Cream and Transparent	cream and Transparent	5	3	Slightly Textured	Slightly Rough and Scratchy	Yes	Yes	

Figure 5.2-21. Rawhide Macroscopic Analysis Criteria.

5.3 Microscopic Analysis of Surface Features

Two microscope and camera assemblages were used during the course of this research. All the tannage types, with the exception of urine tan, were observed and recorded using the Olympus SZ61 stereoscopic microscope and the Olympus DP12 digital camera system, available through the University of Exeter's Archaeology Department. The observation and recording of the museum collections and the urine tan samples from the experimental collection were done using the author's personal Amscope ZTX-3E Stereo microscope, and an Amscope 5MP FMA050 digital camera system purchased to facilitate this research. The portability of this compact microscope and camera system was of great advantage when visiting museum collections, where there was seldom access to an on-site microscope. Using the same camera system for all of the artefact photography increased the comparability of the photographs between the various collections visited.

The sectioning methodology and criteria used to analyse each sample were based, in part, on early leather analysis literature (Dempsey *et al.*, 1984; Reed, 1972; Haines, 1957; 2006). Though many of these sources are early research, they are still the industry standard for low power microscopic observation of leather products. These texts provide a guideline and description of attributes which are still considered important in assessing the quality of finished leather, changes which take place during its conversion into a finished product, and any defects that may be present.

Background information for each sample species

Many of the criteria used for analysis and recorded in the observation tables can be affected by multiple factors, including the age of the animal, sex, and season of harvest. These details were recorded whenever possible for the individual animals whose skins made up the sample collection. This was done in an effort to rule out variation, which could be attributable to the above factors, but which, without this information, might appear to be variation caused by the different tannage types. There are a few samples which are missing this data, where the author had less control over the collecting process, or where the skin was sourced for a use other than this research and the data was not of importance at the time.

As detailed in the de-hairing section of chapter 4 each species was tanned with the hair removed, left in place, or both, depending on the most frequently encountered generalized use of each species. The choice made for each sample is noted in the second column. The age of the animal and the sex have implications for fibre size, thickness, and tightness of weave. Younger animals generally have thinner skins with finer fibres, and often a tighter weave, with the skin thickening and the fibres becoming coarser as the animal ages. As an example of the order of magnitude for this type of variation, an adult cow skin can be twice the thickness of a calf skin (Reed, 1972: 32). The sex of the animal also affects these criteria, with females of a species possessing characteristically thinner, finer-fibred skins than males (Reed, 1972: 36).

The season of harvest can have profound effects on the characteristics of the skin, in part based on the animal's overall condition at different parts of the year, and due to considerations such as, coat variation between the seasons (Klokkernes and Kunstakademi, 2007: 87). There is a general tendency for the skin to thin as the winter progresses and thicken during the summer months, perhaps due to food being more readily available (Kamper, 2016; Tancous, 1986). Enlarged sweat glands are present in many animals during the summer months, and as many of these are located in the already weak area of the mid-dermal junction, their presence can cause the grain layer to delaminate (Haines, 1957: 251). Pests such as warble flies, mange mites, round worms, and even viruses, many of which are seasonal, can cause a variety of lesions, scarring, and thinning of the dermis (Covington, 2011; Haines, 1957).

Observations of Surface Features

The majority of microscopic observations made for this research are of the various surface features of the flesh side and grain sides. This level of observation is non-invasive, making it ideal for analysis of archaeological collections. The surface observations were recorded at set magnifications, which give a comprehensive overview of the range of variation seen across the sample collection. The magnification increments used for most of the recording were 10x, 20x, 30x, and 40x. On occasion, 15x was used when it better highlighted a desired feature. The surface was observed using both top and bottom lighting, which accentuated different aspects of the structural characteristics.

Flesh side

Generally speaking, the flesh side had finer fibres and a flatter appearance than the grain side of the same sample when looking at tannages where the grain had been removed. The fibres showed a more parallel tendency than their grain side counterparts as well. For the sake of consistency, analysis of fibre size, definition, separation and weave were all done on the flesh side of each sample, so as to be applicable whether the grain was intact or not. Tannage types where the grain is not removed do not have observable fibres on the grain side.

At lower magnifications, the flesh side sometimes shows evidence of tool marks from removing the subcutaneous tissues.

Grain Side

Though the grain side was not formally analysed for structural features in keeping with the flesh side, it was systematically photographed, and general tendencies were recorded. On tans where the grain layer is removed, the surface fibres are generally thicker, coarser and more tightly woven than those on the same samples flesh side. The grain side of these de-grained samples often show a 'pits and peaks' type surface topography (Figure. 5.3-1). The completeness of de-graining can vary, with the grain layer of some species being easier to remove than others. The thoroughness of the de-graining process can also reflect the amount of experience the tanner possessed, or their level of commitment to the process. In instances of incomplete grain removal, traces of hair follicles, hair roots and occasionally entire hairs can be identified.

When left intact the grain side is characterised by a smooth, often lustrous surface, dotted with hair follicles and crisscrossed with fine creases. The grain layer is also made up of fibres, however, these extremely fine (45 – 50 nm) fibres are beyond the technical capability of the microscopy employed for the majority of this research (Haines, 1991a: 1). The topography formed by the aforementioned creases varied by species and the level of softness achieved in the underlying fibre network. The patterns created by the hair follicles after the removal of the hair are unique to species. However, without very well-preserved surfaces, identification to the level of species is difficult. Identification to the level of family, such as, deer, bovine or ovicaprid is often feasible.

Speciation is not the main aim of this research, it was however, a question of importance for many of the museums visited. There is already in existence a well-done photographic collection showing the grain pattern of frequently encountered species in Betty Haines (1957) publication, 'Hides, Skins and Leathers Under the Microscope', as well as similar section in Reed's (1972) Ancient Skins, Parchments and Leathers'. A comparative photograph collection will be put together of the more unusual species tanned for this project, as a later addition. For further information on the various methods for determining species see chapter 1 section 1.2.

Thickness

The thickness of each sample was measured using a digital calliper. With the exception of rawhide, the samples are compressible to varying degrees. To overcome the inconsistency this could cause, the samples were measured by applying just enough pressure to touch each surface evenly. Each sample was measured around the entirety of the edge, and the thinnest and thickest measurements recorded. It should be stressed that this range should not be seen as a measurement of thickness for the entire species, as only one individual of each species was measured.

However, it can provide a loose guideline when considering speciation of an archaeological skin find, as some species would fall too far outside the thickness range of the artefact to be considered. The range of thickness varied by tannage type within each species, as was expected, based on the removal of the grain layer for some tannages and not others. However, there was also a difference seen between tannages, where the samples' dermal layers remained intact (urine, alum and vegetable tan). Rawhide was always thinner than the other tannage types. This was in line with expectations as the dermal fibre structure of rawhide compresses significantly as it dries. Vegetable tan was thicker than the other two grain on tannage types, with alum taw somewhat thicker than urine tan. See chapter 6, section 6.1 for details.

A general observation from years of personal tanning experience, combined with the batches of tanning undertaken for this project is that fur bearers have relatively thin skins for their respective sizes. The reason for this is unclear at present, but may have something to do with diet, as most fur bearers such as wild felids, wild canids and the Mustelidae family are carnivores. One notable exception to this thinner skin observation is beaver (*Castor canadensis)* which can be very thick skinned and is herbivorous. The beaver skin acquired for this project was from a young animal and was exceptionally thin for the species and softened relatively easily. This, in the author's experience, is very unusual, in that as a general rule 'the thicker the fur, the thinner the skin'. However, beaver was also the only species in the sample collection that spends much of its time in water, as do otter which also have a relatively thick skin, and it may be that other water mammals such as muskrat, nutria or seals (with which the author has not worked) share this tendency to have very thick skins as an adaptation to their aquatic life styles.

Fibre Size

As previously noted in the introduction section of Chapter 4, the location of the piece of skin used for each species was taken from, approximately, the same area of the body from each individual animal. This area extends from the shoulder to the hip bones, ending approximately halfway down the sides. This area of the skin is relatively even in thickness and was chosen in an effort to make the sample collection as comparable between tannage types within a species, and also between species as possible (Haines, 1991a). This also allows for fibre size comparisons which would suffer less from location-based variations that are seen in areas such as the belly, legs and armpits by using this more even area of skin. That being said, with some of the smaller animals less desirable areas such as legs and lower sides had to be included in order to have enough surface area to obtain six samples from a single animals skin.

While fibre size inevitably differs between species, it also varies to a lesser degree by tannage type. Numerical measurements were not possible using the camera set-up initially available to record microscopic observations. Instead, an ordinal scale was used to describe the size variation. The slides used as a guide for fibres size are presented in Figure. 5.3-2

Fibre Separation

This criterion recorded the degree to which the dermal fibre bundles have separated from one another (Figure. 5.3-3). This degree of separation reflects how well the 3D fibre matrix is maintained as the skin loses its moisture content. This is influenced by the amount of ground substance remaining in the skin, and the degree to which the skin is manipulated during the drying process (Haines, 1991c; Kamper, 2016). A skin with less remaining ground substance will produce a more open and airy fibre structure with a limp drape, while, with more vigorous softening, the same skin's fibres will separate to a greater degree. The amount of separation can also be related to the tannage technology employed (Covington, 1997). The British Leather Manufacture's and Research Association (1957: 11) further distinguish fibre separation by adding fibre splitting when looking at cross sections. Separation is described as being the space between fibre bundles. Splitting is described as the level to which each fibre bundle has separated into fibres, and those fibres further separating into fibrils. This level of differentiation was not possible with surface observations and so, for this research, fibre separation simply describes the amount of space between the fibre bundles.

Fibre weave

Of the criteria recorded, fibre weave is the most difficult to describe in terms of a single visible attribute. It is how tightly the fibres within the fibre structure interweave with each other.

To further illustrate this characteristic, when a species such as goat is described by tanners as having a tighter feel than sheep or (a North American example) Pronghorn, compared to White Tail or Mule Deer, this difference in handle is in large part caused by the level of interwoveness of the fibre structure. While this is a species-based characteristic, there are implications for tannage type based on it. These pertain to the amount of effort required to tan skins where the tightness of the fibre weave varies. Species with a looser fibre structure required less effort, and produced a softer product using the various fat tannages, than species of a similar thickness with a tight fibre structure. This could possibly make species with this looser structure more desirable in areas where fat tanning was the most frequently used technology. The level of tightness present in the fibre weave also affects the appearance of the flesh side, with fuzzier surfaces seen on species with a looser fibre structure.

For example, both wild boar and Galloway cow proved nearly impossible and very difficult, respectively, to soften to any reasonable degree using the fat tanning methods used for this research. This is not to say that these species were not used, but that it is unlikely they would be chosen for clothing production. They would, however, have other uses, such as shoes, armour, tack, containers and straps, where a soft, stretchy handle is less advantageous. If, however, clothing is found made of these species, it may indicate that tannages other than fat tans were in use. If these species are absent from recovered skin artefacts when they are locally available, it may support the hypothesis that the area may have a more limited tanning repertoire.

An attempt has been made to record and visually convey this important characteristic in Figure. 5.3-5.

The raw data for all of the above criteria were recorded into tables for ease of comparison and identification of trends and patterns (Figure. 5.3-6 through Figure. 5.3-11).

The raw data for all of the above criteria were recorded into tables for ease of comparison and identification of trends and patterns (Fig. 5.3-6 through Fig. 5.3-11).

Microscopic Criteria Identification Photographs

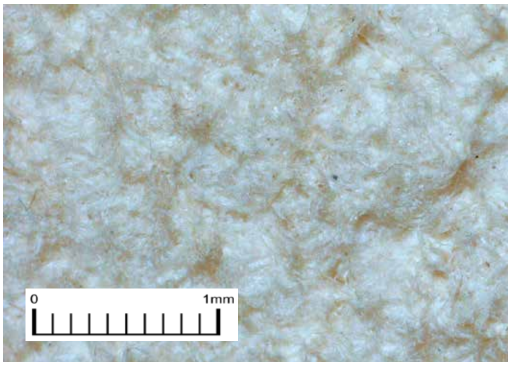


Figure 5.3-1. Grain side surface showing 'pits and peaks' type of surface topography (Mule Deer, *Odocoileus hemionus*) 20x, Scale = 1mm.

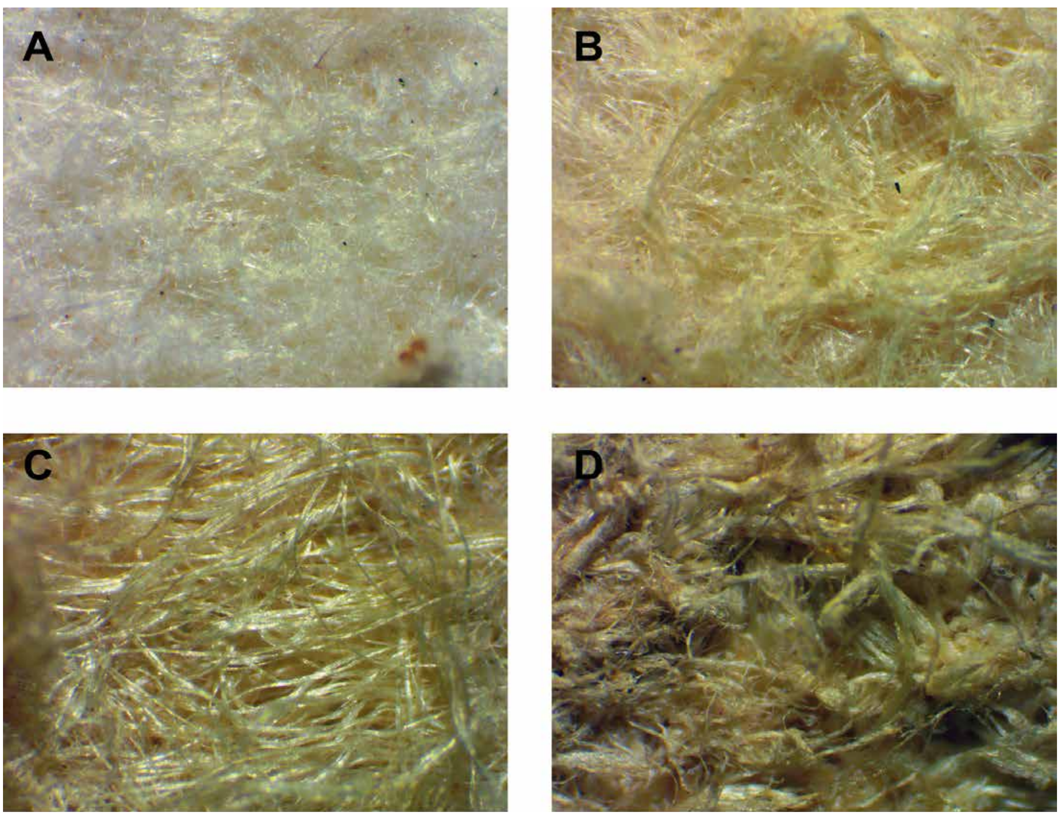


Figure 5.3-2. Fibre Size- **A**: Very Fine, **B**: Fine, **C**: Medium, **D**: Large, **E**: Very Large. Original magnification 40x, Scale = 1mm.

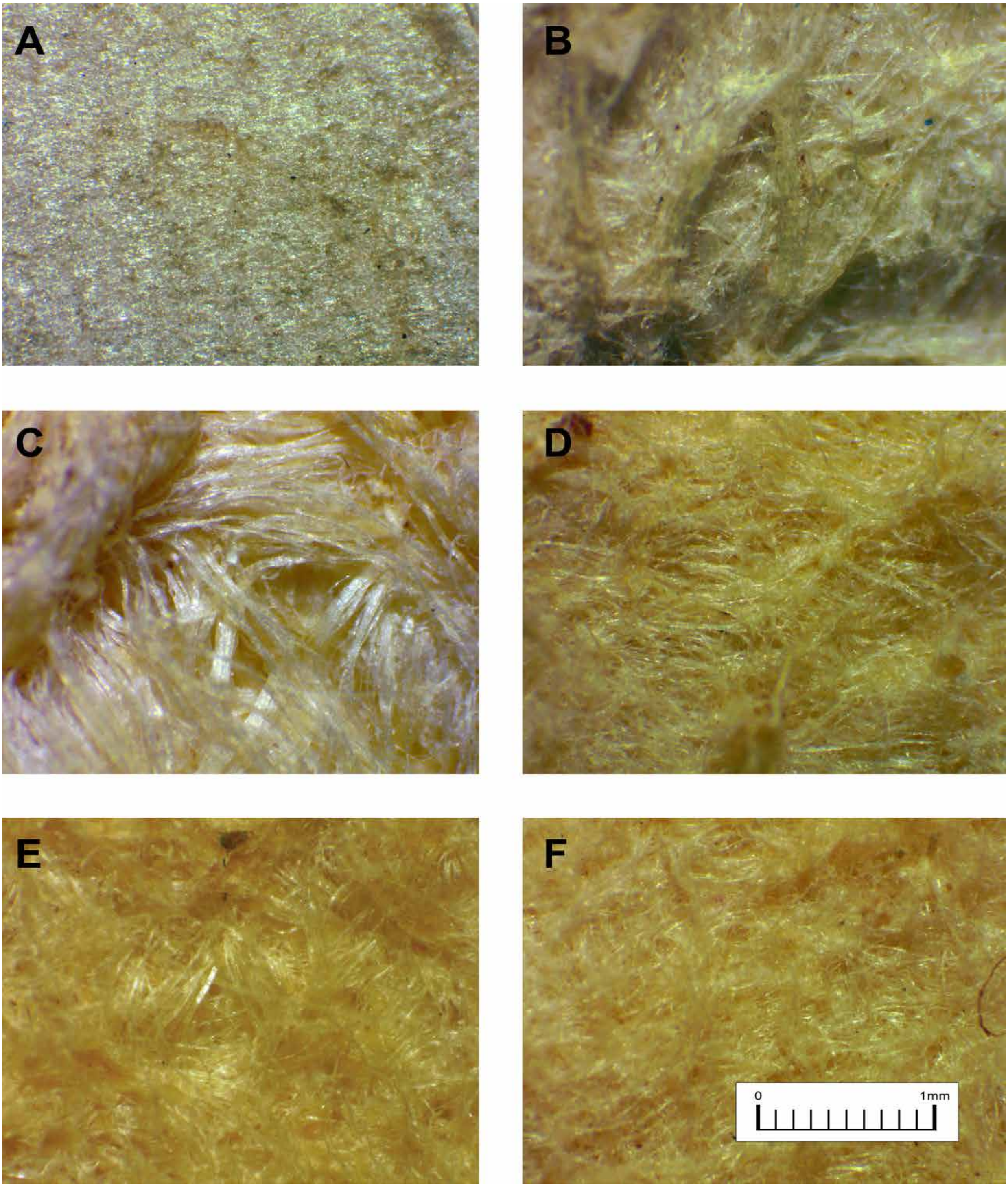


Fig. 5.3-3. Fibre Separation – **A**: No separation, **B**: Poorly separated, **C**: Moderately separated (large fibres), **D**: Moderately separated (fine fibres), **E**: Finely separated, **F**: Very finely separated. Original magnification 40x, Scale = 1mm.

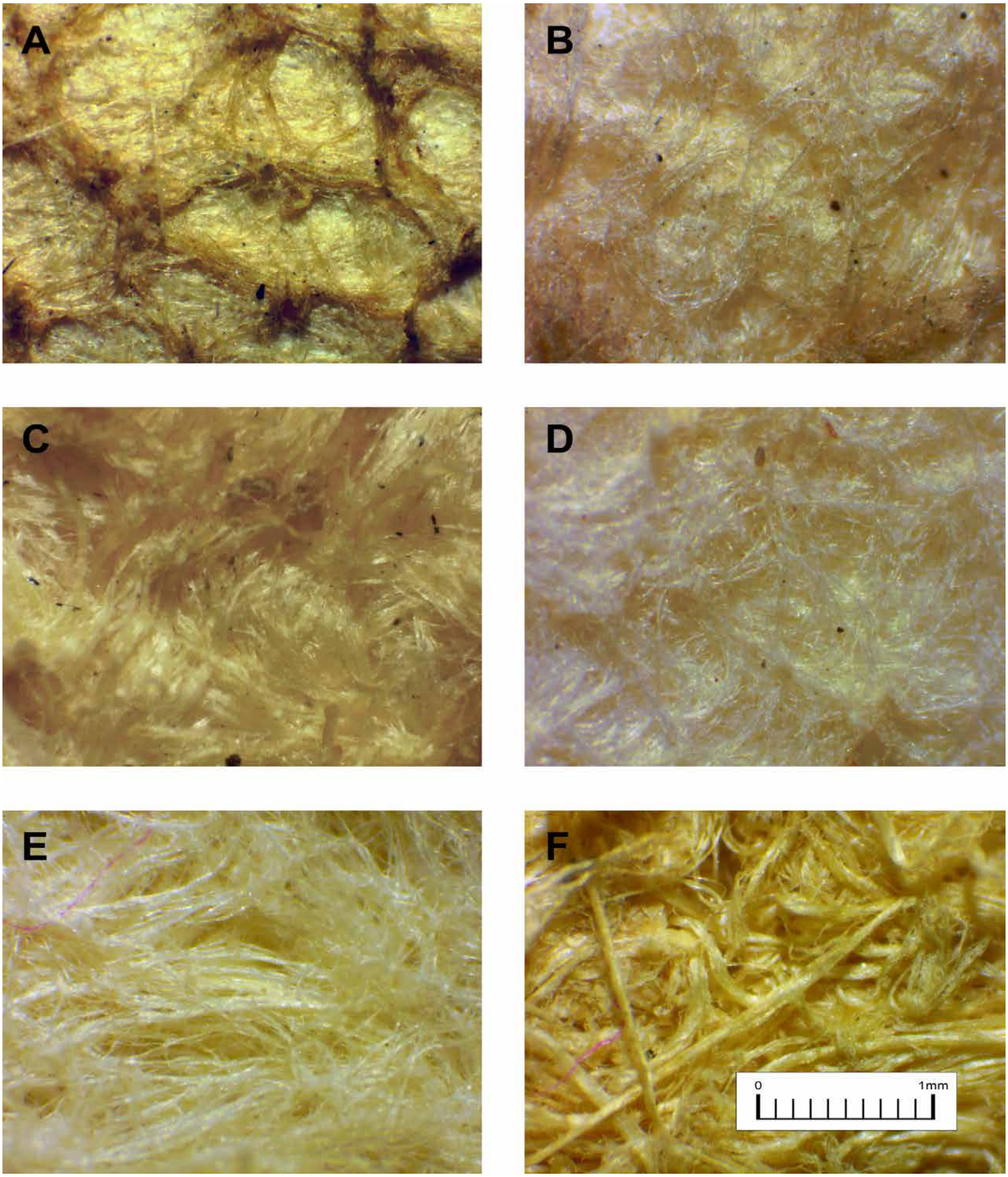


Fig. 5.3-4. Fibre Definition – **A**: Very poorly defined, **B**: Poorly defined, **C**: Moderately defined (large fibres), **D**: Moderately defined (fine fibres), **E**: Well defined, **F**: Very well defined. Original magnification 40x, Scale = 1mm.

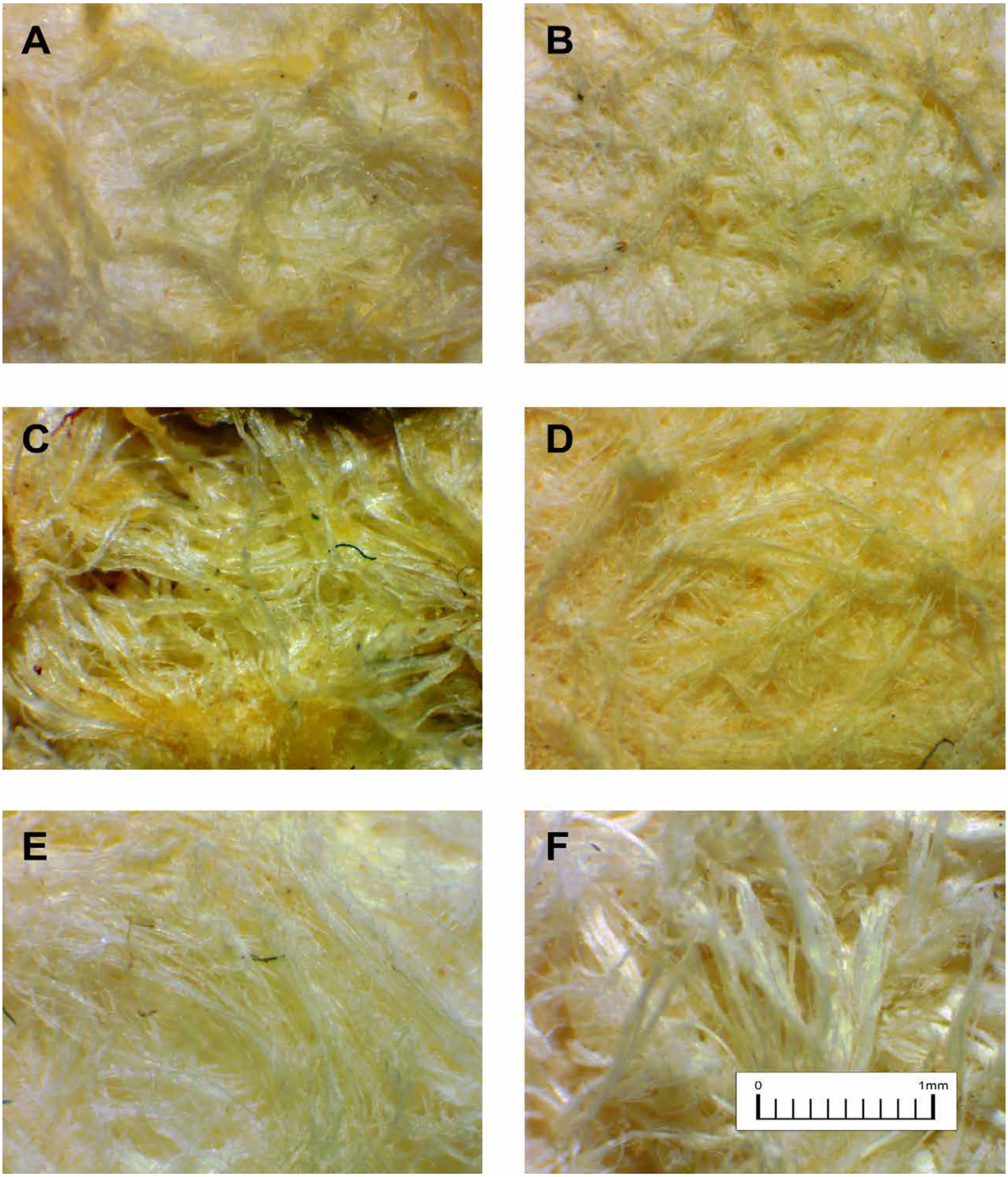


Fig. 5.3-5. Fibre Weave- **A**: Very tightly interwoven, **B**: Tightly interwoven, **C**: Moderately interwoven (thick fibres), **D**: Moderately interwove (fine fibres), **E**: Loosely interwoven, **F**: Very loosely interwoven. Original magnification 40x, Scale = 1mm.

Microscopic Analysis Criteria Tables

Species	Hair on or off	Age	Sex	Season of Harvest	Thickness in mm	Fibre Size	Fibre Weave	Fibre Separation	Fibre Definition
American Badger *Taxidea taxus*	On	Adult	?	Winter	.8 – 2.3	Medium	Moderate	Poor	Moderate
Beaver *Castor Canadensis*	On	Juvenile	?	Winter	.6 – 1.2	Medium	Moderate	Poor	Moderate
American Bison *Bison bison*	On	Adult	F	Early Winter	3.5 – 4.9	Very Large	Very Loose	Fine	Very Well
American Bison *Bison bison*	Off	Adult	F	Early Winter	2.3 – 4.7	Very Large	Loose	Moderate	Very Well
Big Horn Sheep *Ovis Canadensis*	Off	Adult	M	Fall	1.4 – 1.9	Medium	Moderate	Moderate	Moderate
Black Bear *Ursus americanus*	On	Adult	F	Early Winter	1 – 1.5	Large	Loose	Moderate	Well
Canadian Lynx *Lynx canadensis*	On	Juvenile	?	Winter	.9 – 1.2	Very Fine	Tight	Fine	Moderate
American Elk *Cervus Canadensis*	Off	Adult	F	Fall	1.6 – 2.4	Medium	Loose	Fine	Well
Exmoor Pony *Equus ferus caballus*	Off	Infant	M	April	.5 – 1.2	Very Fine	Very Tight	Poor	Poor
Fallow Deer *Dama dama*	Off	Adult	M	Fall	.6 – 1.7	Fine	Tight	Fine	Moderate
Galloway Cow *Bos taurus*	Off	Adult	M	July	2.8 – 4.3	Large	Moderate	Moderate	Well
German Shepherd *Canis lupus familiaris*	On	Juvenile	M	April	.6 – 1.3	Fine	Moderate	Poor	Moderate
Moose *Alces alces*	Off	Adult	M	Late Fall	2 – 3.4	Medium	Loose	Fine	Very Well
Mule Deer *Odocoileus virginianus*	Off	Adult	M	Fall	.8 – 1.1	Very Fine	Tight	Fine	Moderate
Pronghorn Antelope *Antilocapra americana*	Off	Adult	F	Fall	.4 – .7	Fine	Tight	Moderate	Moderate
Rabbit *Sylvilagus sp*	On	Geriatric	M	?	.6 – 1.2	Very Fine	Tight	Poor	Poor
Red Deer *Cervus elaphus*	Off	Adult	F	Fall	1 – 1.6	Medium	Moderate	Moderate	Well
Red Fox *Vulpes vulpes*	On	Adult	?	Late Winter	.2 – .6	Very Fine	Tight	Poor	Poor
Reindeer/Caribou *Rangifer tarandus*	On	Unknown	?	Winter	.7 – 1.2	Fine	Moderate	Well	Moderate
Reindeer/Caribou *Rangifer tarandus*	Off	Unknown	?	Winter	.8 – 1.4	Fine	Moderate	Moderate	Moderate
Roe Deer *Capreolus capreolus*	Off	Adult	F	March	.5 – 1.6	Very Fine	Tight	Moderate	Well
Soay Sheep *Ovis aries*	On	Adult	F	May	.7 – 1.2	Very Fine	Very Tight	Poor	Moderate
Soay Sheep *Ovis aries*	Off	Adult	F	May	.6 – 1	Very Fine	Tight	Moderate	Well
Toggenburg Goat *Capra aegagrus hircus*	On	Juvenile	M	December	1.5 – 2.6	Fine	Tight	Moderate	Well
Toggenburg Goat *Capra aegagrus hircus*	Off	Juvenile	M	December	1.3 – 2.5	Medium	Tight	Moderate	Well

Figure 5.3-6. Alum Taw Microscopic Analysis Criteria.

Species	Hair on or off	Age	Sex	Season of Harvest	Thickness	Fibre Size	Fibre Weave	Fibre Separation	Fibre Definition
American Badger *Taxidea taxus*	On	Adult	?	Winter	.9 – 2	Medium	Tight	Poor	Moderate
Beaver *Castor Canadensis*	On	Juvenile	?	Winter	.6 – 1.4	Fine	Moderate	Moderate	Well
American Bison *Bison bison*	On	Adult	F	Early Winter	4 – 5.8	Very Large	Loose	Moderate	Well
American Bison *Bison bison*	Off	Adult	F	Early Winter	7 – 8.3	Very Large	Loose	Poor	Moderate
Big Horn Sheep *Ovis Canadensis*	Off	Adult	M	Fall	1.1 – 2. 2	Fine	Moderate	Moderate	Well
Black Bear *Ursus americanus*	On	Adult	F	Early Winter	1.1 – 2	Large	Moderate	Moderate	Moderate
Canadian Lynx *Lynx canadensis*	On	Juvenile	?	Winter	.6 -1.3	Fine	Tight	Moderate	Moderate
American Elk *Cervus Canadensis*	Off	Adult	F	Fall	2.2 – 3.3	Medium	Loose	Moderate	Well
Exmoor Pony *Equus ferus caballus*	Off	Infant	M	April	.8 – 1.3	Fine	Tight	Moderate	Moderate
Fallow Deer *Dama dama*	Off	Adult	M	Fall	.9 – 1.3	Medium	Moderate	Moderate	Well
Galloway Cow *Bos taurus*	Off	Adult	M	July	5.4 – 6.6	Large	Tight	Moderate	Very Well
German Shepherd *Canis lupus familiaris*	On	Juvenile	M	April	.7 – 1.7	Medium	Moderate	Moderate	Well
Moose *Alces alces*	Off	Adult	M	Late Fall	3.4 -4.7	Medium	Loose	Moderate	Well
Mule Deer *Odocoileus virginianus*	Off	Adult	M	Fall	.8 – 1.5	Medium	Tight	Moderate	Well
Pronghorn Antelope *Antilocapra americana*	Off	Adult	F	Fall	.8 – 1.1	Fine	Moderate	Fine	Well
Rabbit *Sylvilagus sp*	On	Geriatric	M	?	.6 – 1.5	Very Fine	Very Tight	Moderate	Moderate
Red Deer *Cervus elaphus*	Off	Adult	F	Fall	1.7 – 2.7	Medium	Loose	Fine	Well
Red Fox *Vulpes vulpes*	On	Adult	?	Late Winter	.1 – .5	Fine	Tight	Poor	Moderate
Reindeer/Caribou *Rangifer tarandus*	On	Unknown	?	Winter	.9 – 1.5	Fine	Moderate	Poor	Moderate
Reindeer/Caribou *Rangifer tarandus*	Off	Unknown	?	Winter	1 – 1.5	Fine	Moderate	Poor	Moderate
Roe Deer *Capreolus capreolus*	Off	Adult	F	March	1.1 – 2.4	Very Fine	Tight	Moderate	Moderate
Soay Sheep *Ovis aries*	On	Adult	F	May	1 – 1.6	Very Fine	Tight	Moderate	Moderate
Soay Sheep *Ovis aries*	Off	Adult	F	May	.8 – 1.4	Very Fine	Tight	Moderate	Moderate
Toggenburg Goat *Capra aegagrus hircus*	On	Juvenile	M	December	1.9 – 3	Medium	Tight	Moderate	Well
Toggenburg Goat *Capra aegagrus hircus*	Off	Juvenile	M	December	1.4 – 2.3	Medium	Tight	Poor	Well
Wild Boar *Sus scrofa*	Off	Juvenile	M	May	1.4 – 2.9	Medium	Very Tight	Very Poor	Very Poor

Figure 5.3-7. Vegetable Tan Microscopic Analysis Criteria.

Species	Hair on or off	Age	Sex	Season of Harvest	Thickness in mm	Fibre Size	Fibre Weave	Fibre Separation	Fibre Definition
American Badger *Taxidea taxus*	On	Adult	?	Winter	.9 – 1.6	Medium	Moderate	Moderate	Moderate
Beaver *Castor Canadensis*	On	Juvenile	?	Winter	.4- .9	Medium	Moderate	Moderate	Well
American Bison *Bison bison*	On	Adult	F	Early Winter	2.9 – 4.2	Very Large	Loose	Moderate	Very Well
American Bison *Bison bison*	Off	Adult	F	Early Winter	3.5 – 5	Very Large	Very Loose	Moderate	Very Well
Big Horn Sheep *Ovis Canadensis*	Off	Adult	M	Fall	.6 – 1	Medium	Tight	Moderate	Well
Black Bear *Ursus americanus*	On	Adult	F	Early Winter	.9 – 1.2	Medium	Moderate	Fine	Moderate
Canadian Lynx *Lynx canadensis*	On	Juvenile	?	Winter	.2 – .4	Very Fine	Tight	Fine	Poor
American Elk *Cervus Canadensis*	Off	Adult	F	Fall	.8 – 1.4	Medium	Very Loose	Moderate	Very Well
Exmoor Pony *Equus ferus caballus*	Off	Infant	M	April	.5 – .7	Very Fine	Tight	Very Fine	Poor
Galloway Cow *Bos taurus*	Off	Adult	M	July	2.2 – 2.8	Large	Moderate	Poor	Very Well
German Shepherd *Canis lupus familiaris*	On	Juvenile	M	April	.5 – .9	Fine	Loose	Fine	Well
Moose *Alces alces*	Off	Adult	M	Late Fall	1.5 – 2	Medium	Loose	Fine	Well
Mule Deer *Odocoileus virginianus*	Off	Adult	M	Fall	.8 – 1.1	Very Fine	Moderate	Fine	Moderate
Pronghorn Antelope *Antilocapra americana*	Off	Adult	F	Fall	.6 – 1	Fine	Tight	Fine	Moderate
Rabbit *Sylvilagus sp*	On	Geriatric	M	?	.2 – .6	Very Fine	Moderate	Fine	Moderate
Red Deer *Cervus elaphus*	Off	Adult	F	Fall	.8 – 1.7	Medium	Moderate	Moderate	Well
Red Fox *Vulpes vulpes*	On	Adult	?	Late Winter	.2 – .4	Very Fine	Moderate	Poor	Well
Reindeer/Caribou *Rangifer tarandus*	On	Unknown	?	Winter	.6 – 1.1	Fine	Tight	Moderate	Moderate
Reindeer/Caribou *Rangifer tarandus*	Off	Unknown	?	Winter	.6 – 1	Fine	Tight	Fine	Well
Roe Deer *Capreolus capreolus*	Off	Adult	F	March	.5 – .9	Very Fine	Tight	Very Fine	Moderate
Soay Sheep *Ovis aries*	On	Adult	F	May	.4 – .6	Very Fine	Tight	Fine	Moderate
Soay Sheep *Ovis aries*	Off	Adult	F	May	.3 – .5	Fine	Tight	Fine	Well
Toggenburg Goat *Capra aegagrus hircus*	Off	Juvenile	M	December	.4 – .8	Medium	Tight	Moderate	Well

Figure 5.3-8. Wet Scrape Brain Tan Microscopic Analysis Criteria.

Species	Hair on or off	Age	Sex	Season of Harvest	Thickness in mm	Fibre Size	Fibre Weave	Fibre Separation	Fibre Definition
American Badger *Taxidea taxus*	On	Adult	?	Winter	.9 – 1.6	Medium	Tight	Moderate	Very Well
Beaver *Castor Canadensis*	On	Juvenile	?	Winter	.3 – .6	Fine	Moderate	Fine	Moderate
American Bison *Bison bison*	On	Adult	F	Early Winter	4.6 – 5.6	Very Large	Loose	Moderate	Well
American Bison *Bison bison*	Off	Adult	F	Early Winter	3.8 – 4	Very Large	Very Loose	Moderate	Very Well
Big Horn Sheep *Ovis Canadensis*	Off	Adult	M	Fall	1.1 -1.4	Medium	Moderate	Moderate	Well
Black Bear *Ursus americanus*	On	Adult	F	Early Winter	1.1 – 1.5	Medium	Loose	Fine	Moderate
American Elk *Cervus Canadensis*	Off	Adult	F	Fall	1.8 – 2.3	Medium	Very Loose	Moderate	Well
Exmoor Pony *Equus ferus caballus*	Off	Infant	M	April	.4 – .8	Fine	Tight	Poor	Well
Fallow Deer *Dama dama*	Off	Adult	M	Fall	.9 -1.3	Fine	Moderate	Fine	Well
Galloway Cow *Bos taurus*	Off	Adult	M	July	2 – 2.8	Large	Moderate	Moderate	Well
German Shepherd *Canis lupus familiaris*	On	Juvenile	M	April	.5 – .7	Medium	Moderate	Moderate	Well
Moose *Alces alces*	Off	Adult	M	Late Fall	1.9 – 2.4	Medium	Loose	Moderate	Well
Mule Deer *Odocoileus virginianus*	Off	Adult	M	Fall	.9 – 1.1	Very Fine	Tight	Very Fine	Moderate
Pronghorn Antelope *Antilocapra americana*	Off	Adult	F	Fall	.8 – 1	Very Fine	Very Tight	Fine	Moderate
Red Deer *Cervus elaphus*	Off	Adult	F	Fall	1.4 -1.6	Fine	Moderate	Fine	Poor
Red Fox *Vulpes vulpes*	On	Adult	?	Late Winter	.3 – .5	Very Fine	Tight	Moderate	Poor
Reindeer/Caribou *Rangifer tarandus*	On	Unknown	?	Winter	.6 – 1.2	Fine	Tight	Fine	Well
Reindeer/Caribou *Rangifer tarandus*	Off	Unknown	?	Winter	.5 – .9	Fine	Tight	Fine	Well
Roe Deer *Capreolus capreolus*	Off	Adult	F	March	.7 – 1	Very Fine	Moderate	Very Fine	Poor
Soay Sheep *Ovis aries*	On	Adult	F	May	.5 – .8	Very Fine	Tight	Fine	Moderate
Soay Sheep *Ovis aries*	Off	Adult	F	May	.3 – .6	Very Fine	Tight	Fine	Moderate
Toggenburg Goat *Capra aegagrus hircus*	On	Juvenile	M	December	.7 -.9	Fine	Tight	Moderate	Moderate
Toggenburg Goat *Capra aegagrus hircus*	Off	Juvenile	M	December	.9 -1.4	Fine	Tight	Moderate	Moderate
Wild Boar *Sus scrofa*	Off	Juvenile	M	May	1.6 – 2.6	Medium		Poor	Moderate

Figure 5.3-9. Dry Scrape Brain Tan Microscopic Analysis Criteria.

Species	Hair on or off	Age	Sex	Season of Harvest	Thickness in mm	Fibre Size	Fibre Weave	Fibre Separation	Fibre Definition
American Badger *Taxidea taxus*	On	Adult	?	Winter	.6 – 1.8	Large	Moderate	Poor	Moderate
Beaver *Castor Canadensis*	On	Juvenile	?	Winter	.4 – .9	Fine	Tight	Poor	Well
American Bison *Bison bison*	Off	Adult	F	Early Winter	2.5 – 4.2	Very Large	Very Loose	Fine	Very Well
Big Horn Sheep *Ovis Canadensis*	Off	Adult	M	Fall	.7 – 1	Medium	Moderate	Fine	Well
Black Bear *Ursus americanus*	On	Adult	F	Early Winter	.8 – 1.4	Medium	Loose	Moderate	Well
Canadian Lynx *Lynx canadensis*	On	Juvenile	?	Winter	.2 – .5	Very Fine	Tight	Fine	Moderate
American Elk *Cervus Canadensis*	Off	Adult	F	Fall	1 -1 .4	Medium	Loose	Moderate	Well
Exmoor Pony *Equus ferus caballus*	Off	Infant	M	April	.3 -.5	Very Fine	Tight	Moderate	Well
Fallow Deer *Dama dama*	Off	Adult	M	Fall	.5 – .9	Fine	Tight	Very Poor	Moderate
Galloway Cow *Bos taurus*	Off	Adult	M	July	1.7 – 2.5	Large	Tight	Moderate	Moderate
German Shepherd *Canis lupus familiaris*	On	Juvenile	M	April	.5 – .8	Fine	Tight	Moderate	Moderate
Moose *Alces alces*	Off	Adult	M	Late Fall	1.2 – 1.7	Medium	Loose	Fine	Well
Mule Deer *Odocoileus virginianus*	Off	Adult	M	Fall	.3 – .6	Fine	Tight	Poor	Moderate
Pronghorn Antelope *Antilocapra americana*	Off	Adult	F	Fall	.3 – .5	Very Fine	Very Tight	Fine	Moderate
Rabbit *Sylvilagus sp*	On	Geriatric	M	?	.2 – .6	Very Fine	Very Tight	Poor	Poor
Red Deer *Cervus elaphus*	Off	Adult	F	Fall	.9 – 1.8	Medium	Loose	Moderate	Moderate
Red Fox *Vulpes vulpes*	On	Adult	?	Late Winter	.9 – .4	Very Fine	Tight	Poor	Poor
Reindeer/Caribou *Rangifer tarandus*	Off	Unknown	?	Winter	.6 – .9	Fine	Moderate	Moderate	Well
Roe Deer *Capreolus capreolus*	Off	Adult	F	March	.4 – 1	Very Fine	Very Tight	Moderate	Poor
Soay Sheep *Ovis aries*	On	Adult	F	May	.6 – .8	Very Fine	Tight	Moderate	Moderate
Soay Sheep *Ovis aries*	Off	Adult	F	May	.4 – .7	Very Fine	Tight	Moderate	Well
Toggenburg Goat *Capra aegagrus hircus*	On	Juvenile	M	December	.6 – 1.2	Very Fine	Tight	Poor	Moderate
Toggenburg Goat *Capra aegagrus hircus*	Off	Juvenile	M	December	.6 – .8	Very Fine	Tight	Fine	Moderate

Figure 5.3-10. Urine Tan Microscopic Analysis Criteria.

Species	Hair on or off	Age	Sex	Season of Harvest	Thickness in mm	Fibre Size	Fibre Weave	Fibre Separation	Fibre Definition
American Badger *Taxidea taxus*	On	Adult	?	Winter	.6 – 1.5	Medium	Not Visible	No Separation	Very Poor
Beaver *Castor Canadensis*	On	Juvenile	?	Winter	.5 – .8	Not Visible	Not Visible	No Separation	None
American Bison *Bison bison*	On	Adult	F	Early Winter	3.5 – 5	Very Large	Not Visible	No Separation	Poor
American Bison *Bison bison*	Off	Adult	F	Early Winter	2.8 – 3.8	Very Large	Not Visible	No Separation	Very Poor
Big Horn Sheep *Ovis Canadensis*	Off	Adult	M	Fall	1.6 – 1.9	Fine	Not Visible	No Separation	Very Poor
Black Bear *Ursus americanus*	On	Adult	F	Early Winter	.6 -1.2	Medium	Not Visible	No Separation	Very Poor
Canadian Lynx *Lynx canadensis*	On	Juvenile	?	Winter	.1 – .2	Fine	Not Visible	No Separation	Very Poor
American Elk *Cervus Canadensis*	Off	Adult	F	Fall	.6 – 1.4	Not Visible	Not Visible	No Separation	None
Exmoor Pony *Equus ferus caballus*	Off	Infant	M	April	.2 – .3	Very Fine	Not Visible	No Separation	Very Poor
Fallow Deer *Dama dama*	Off	Adult	M	Fall	.2 -.3	Not Visible	Not Visible	No Separation	None
Galloway Cow *Bos taurus*	Off	Adult	M	July	1.5 – 2.2	Large	Not Visible	No Separation	Very Poor
German Shepherd *Canis lupus familiaris*	On	Juvenile	M	April	.5 – .9	Not Visible	Not Visible	No Separation	None
Moose *Alces alces*	Off	Adult	M	Late Fall	1.3 – 2.4	Medium	Not Visible	No Separation	Very Poor
Mule Deer *Odocoileus virginianus*	Off	Adult	M	Fall	.3 – .4	Very Fine	Not Visible	No Separation	Very Poor
Pronghorn Antelope *Antilocapra americana*	Off	Adult	F	Fall	.3 – .4	Not Visible	Not Visible	No Separation	None
Rabbit *Sylvilagus sp*	On	Geriatric	M	?	.4 – .7	Not Visible	Not Visible	No Separation	None
Red Deer *Cervus elaphus*	Off	Adult	F	Fall	.4 – .6	Not Visible	Not Visible	No Separation	None
Red Fox *Vulpes vulpes*	On	Adult	?	Late Winter	.3 – .5	Not Visible	Not Visible	No Separation	None
Reindeer/Caribou *Rangifer tarandus*	On	Unknown	?	Winter	.3 – .6	Not Visible	Not Visible	No Separation	None
Reindeer/Caribou *Rangifer tarandus*	Off	Unknown	?	Winter	.5 – .8	Not Visible	Not Visible	No Separation	None
Roe Deer *Capreolus capreolus*	Off	Adult	F	March	.3 – .6	Not Visible	Not Visible	No Separation	None
Soay Sheep *Ovis aries*	On	Adult	F	May	.5 – .7	Not Visible	Not Visible	No Separation	None
Soay Sheep *Ovis aries*	Off	Adult	F	May	.4 – .6	Not Visible	Not Visible	No Separation	None
Toggenburg Goat *Capra aegagrus hircus*	On	Juvenile	M	December	1 – 1.2	Not Visible	Not Visible	No Separation	None
Toggenburg Goat *Capra aegagrus hircus*	Off	Juvenile	M	December	.6 – 1.3	Not Visible	Not Visible	No Separation	None

Figure 5.3-11. Rawhide Microscopic Analysis Criteria.

5.4 Low-Power Microscopic Cross Section Analysis

The unique character of skin is due to the 3-dimensional interweaving of its collagen fibres. These fibres can be viewed in a different way using cross sections than is possible with surface observations. Compactness becomes a more visible trait, whereas with entire skin samples it is a more tactile assessment. Cross sections allow fibres, which have not been affected by the often-abrasive methods used during the softening process, to be viewed. It is hoped that, in observing these cross sections, the interior structures of the samples can be assessed for variation caused by the different tannage types, which would not be visible from microscopic observations of the sample's flesh or grain-side surfaces. The following analysis of the cross sections, the criteria, and their descriptions are partially based on designations used to assess leather quality in 'Hides, skins, and leather under the microscope' (Haines, 1957). The descriptions have, in some cases, been modified to reflect the differing goals of this research, with emphasis being placed on criteria likely to highlight differences due to tannage type.

Fibre Size

The same ordinal scale that was used previously in the surface analysis section was used to assess fibre size. This was done to maintain consistency with the surface assessments done previously. It was feared, however, that this ordinal scale might be masking some size variations caused by tannage type, as the ordinal scale might not be fine enough for these subtle differences to show up. In an effort to assess this bias, fibres from the two species chosen for individual fibre analysis were digitally measured, as access to the technology necessary for this had become available toward the end of this research. The details from these measurements are outlined in section 5.5.

Fullness

This term is used by the British Leather Manufacturing and Research Association (BLMRA) to refer to the size of the diameter of the fibre or fibre bundle. The size range observed can be a result of differing fibre size between species, or it can be caused by plumping due to soaking in an alkaline (or acidic) solution (Haines, 1957: 12). For this research, 'fullness' indicates the cross section shape of the fibres, from flat and ribbon-like to round and plump. Figure. 5.4-1 and 5.4-2 illustrate this characteristic when seen as an individual fibre, and as in situ fibres within the dermal structure.

Splitting Up

'Splitting up' is defined as the separation of fibre bundles into fibres, and fibres into fibrils. Skins which have had the fibre structure opened up by the removal of the non-collagenous proteins (ground substance) have more spaces between the sub-units. When these spaces are maintained, soft flexible leather will result. However, if a percentage of this splitting up is allowed to re-stick, the end product will be leather with a firmer handle and a more compact structure. (Haines, 1991a: 3; 1957: 10). This attribute is illustrated in Figure. 5.4-3 and Figure. 5.4-4.

Appearance of the Fibre Network

The general appearance of the fibre network was noted, though this was much easier to see on the larger fibred species and on the more compact tannage types such as vegetable tan and alum taw. The appearance was recorded along the classifications set out by Haines (1957: 13), which takes into account the general appearance of the fibre's curvature when interweaving. The designations 'straight', 'large curves', 'small curves', 'crinkle' and 'disordered' were used. These characteristics are outlined in Figure. 5.4-5.

Angle of Weave

This refers to the general angle of the mid-dermal fibres in relation to the grain and flesh side surfaces. This weave angle varies from the flesh side to the grain side, with the fibres closest to the flesh side running more horizontally, and the mid-dermis fibres increasing in angle toward to grain side. When stating the angle, it is the general trend which is being referred to. The angle of weave is in part a species-based characteristic, however, the tannage type and pre-tanning treatments applied can affect this quality. For example, when placed in an alkaline solution, the dermal fibres swell and the angle of weave increases. Depending on how swollen the fibres are allowed to remain after being soaked in an alkaline or acid solution before being placed in a tanning solution, the tanner has some control over the angle of weave (Haines, 1991a: 3). This particular control has limited use for the tannages covered by this research and applies mostly to vegetable tannage and possibly alum taw. Alternatively, a second example is when a skin is dried with little manipulation, as is the case with rawhide – the angle of weave is very low due to the collapse and resticking of the fibre structure into horizontal layers.

A 'horizontal angle' refers to fibres which run roughly parallel to the flesh and grain side surfaces with little interweaving, often showing as parallel layers. A 'low angle' refers to fibres which have an acceptable amount of interwovenness, just at a low angle. A 'medium angle' has the majority of fibres cross over at approximately 45^{o}, and a high angle sees them interweave an angle of 70^{o}-90^{o} (Haines, 1957: 10). These are illustrated in Figure. 5.4-6.

Compactness

When looking at the cross sections for this research, 'compactness' refers to the density of the fibre structure observed. The term 'compactness' is used in keeping with the BLMRA standards (Haines, 1957: 10), but the three divisions given in this literature did not adequately describe the extreme opposite ends of the scale of compactness seen in the samples. Therefore, to provide a more nuanced scale, the division of the categories and their definitions are the author's.

A 'cemented structure' has few, if any, visible fibres, and little to no interweaving of the fibres. A 'compact structure' has little space between the fibres, little splitting up, and is tightly interwoven. 'Moderately compact' is defined by some space between the fibre bundles, a moderate amount of splitting up, and interwovenness. 'Loose' or 'airy' refers to cross sections with a very open structure, with space between the fibres, often a great deal of splitting up, and normally medium to loosely interwoven fibres. Figure.5.4-7 illustrates the differing levels of compactness seen in the cross sections.

The data for the above criteria has been consolidated into tables and can be found at the end of this section in Figure. 5.4-8 through Figure. 5.4-13.

Cross Section Characteristic Identification Photographs

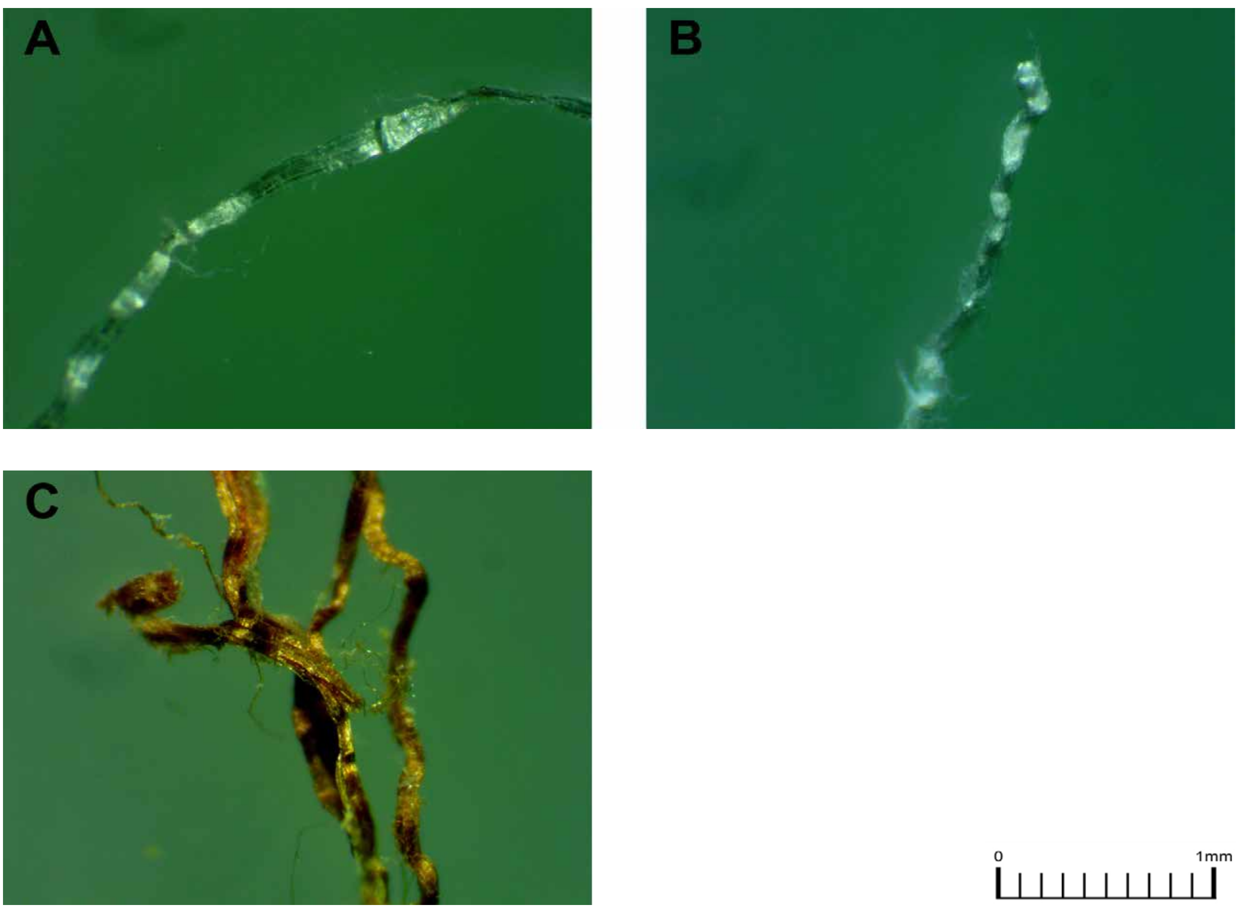
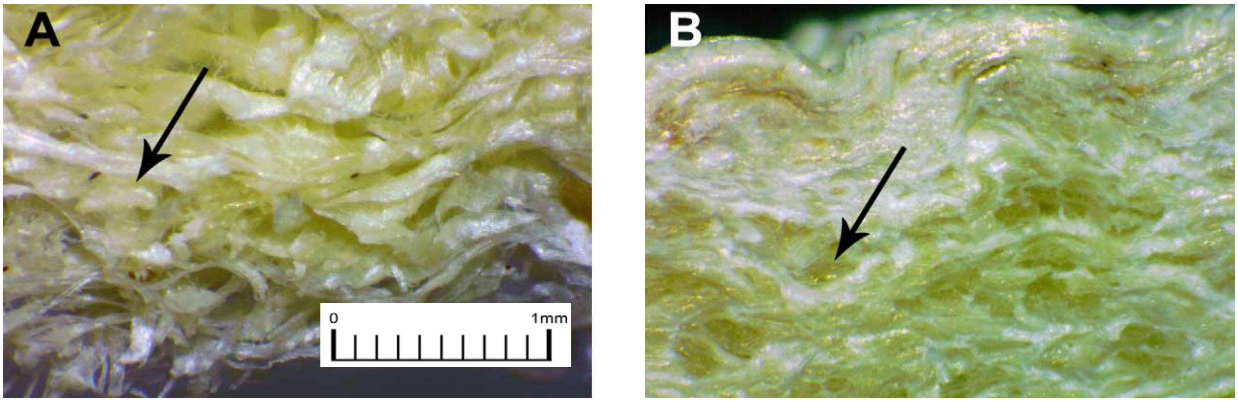


Fig. 5.4-1. Fullness of Fibre Shape- **A**: Flat ribbon like fibre, **B**: Moderately full fibres, **C**: Full, plump fibres. Species Bison, Original magnification 40x, Scale = 1mm.



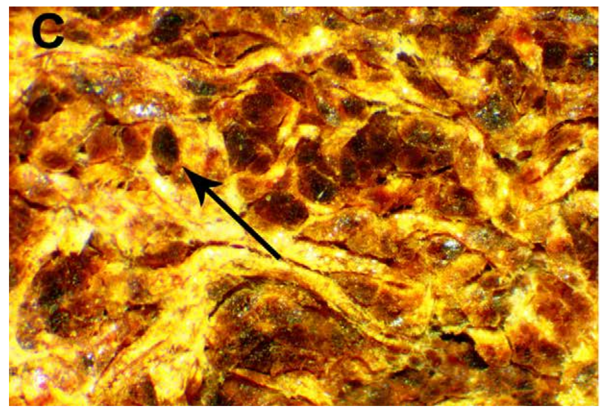
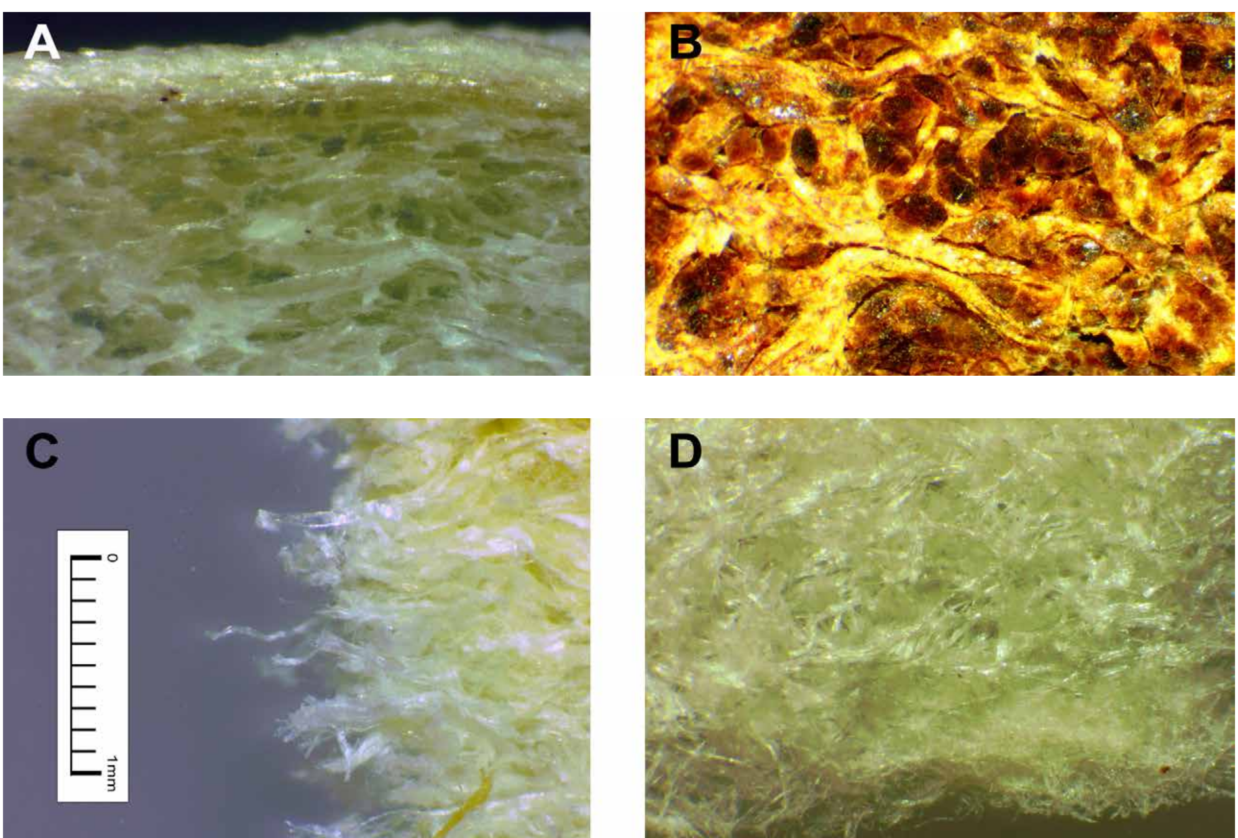


Fig. 5.4-2. Fullness of In Situ Fibres- **A**: Flat ribbon like fibres, **B**: Moderately full fibres, **C**: Full rounded fibres. Species Bison, Original magnification 40x, Scale = 1mm.

Fig. 5.4-3. Splitting Up of Fibre Bundles- **A**: No splitting, **B**: Little splitting, **C**: Moderate splitting, **D**: Finely split up. Original magnification 40x, Scale = 1mm.



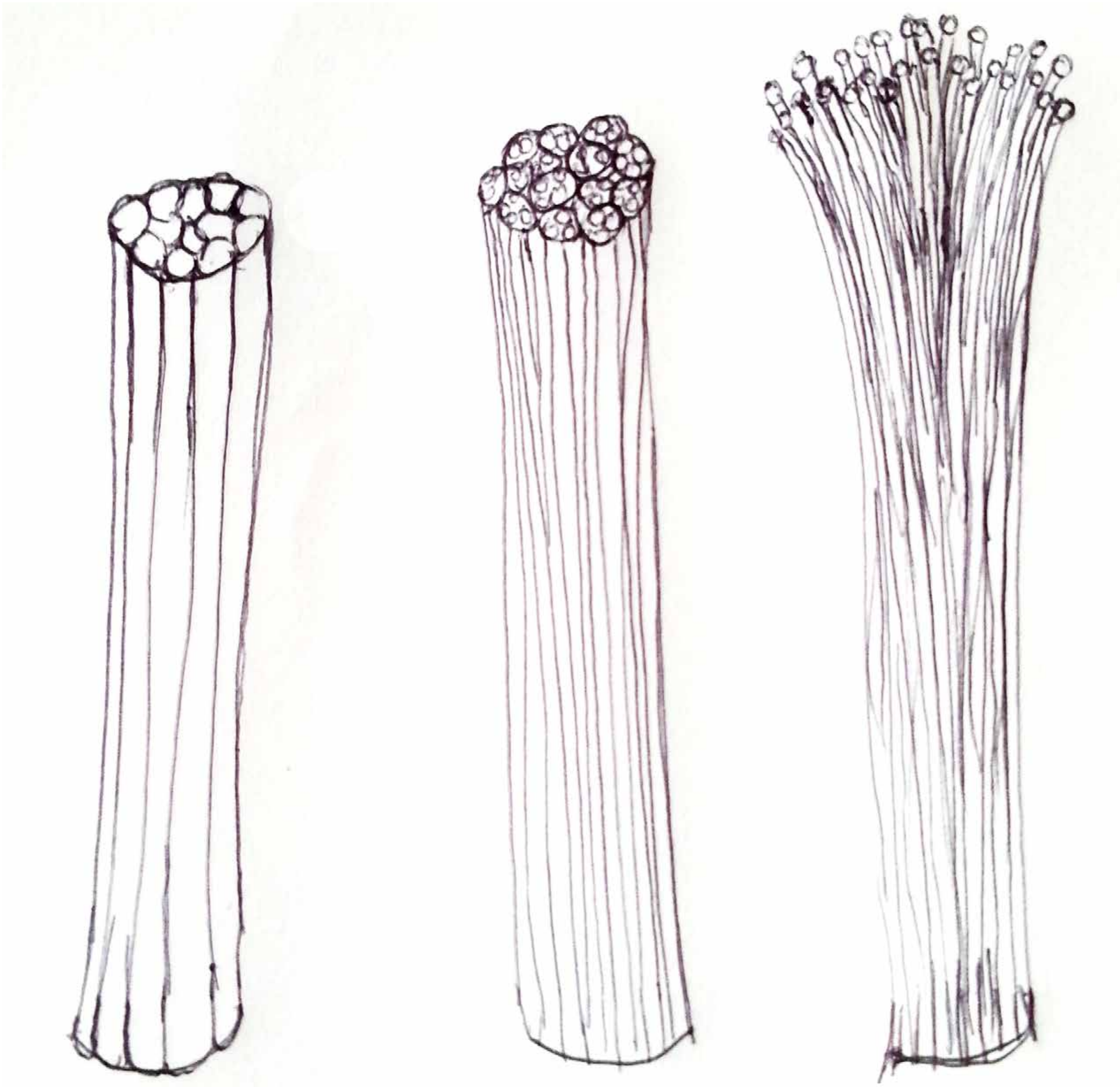


Fig. 5.4-4. Drawing of Splitting up- Left: Fibre bundle with little splitting up into fibres. Middle: Fibre bundle moderately split into individual fibres. Right: Fibre bundle finely split up into fibres. This makes the fibres look similar to cotton candy. (based on Association, 1957, pg. 11).

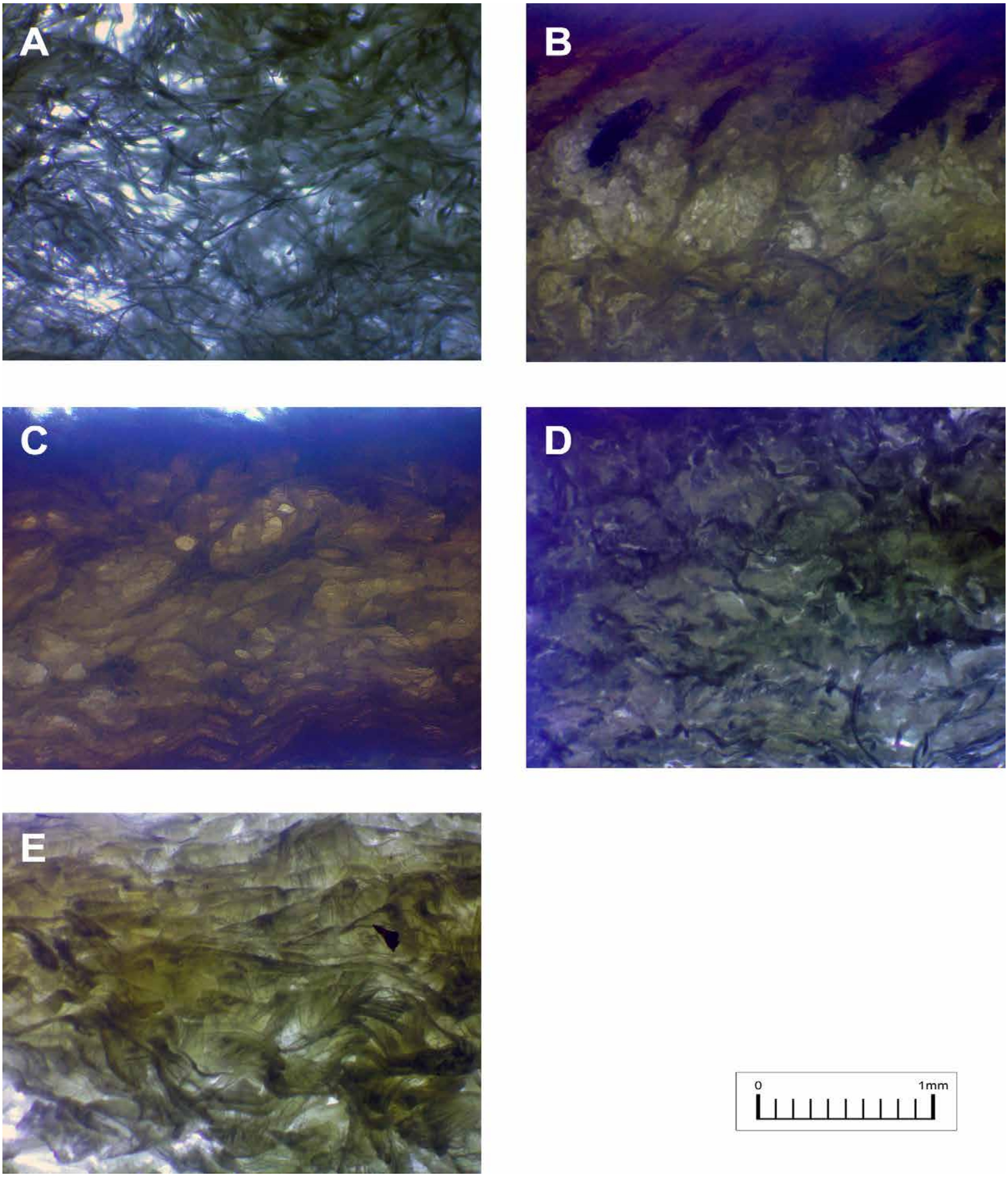
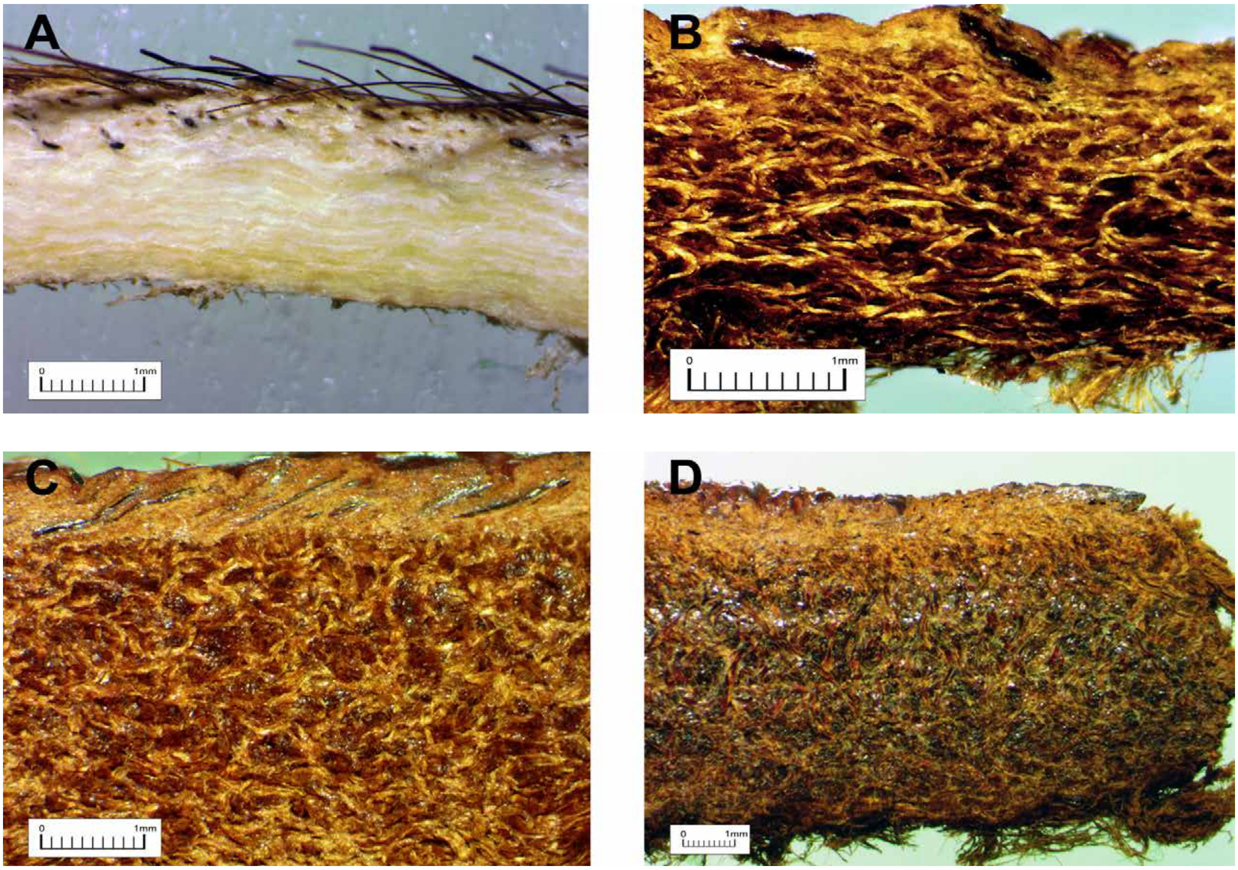
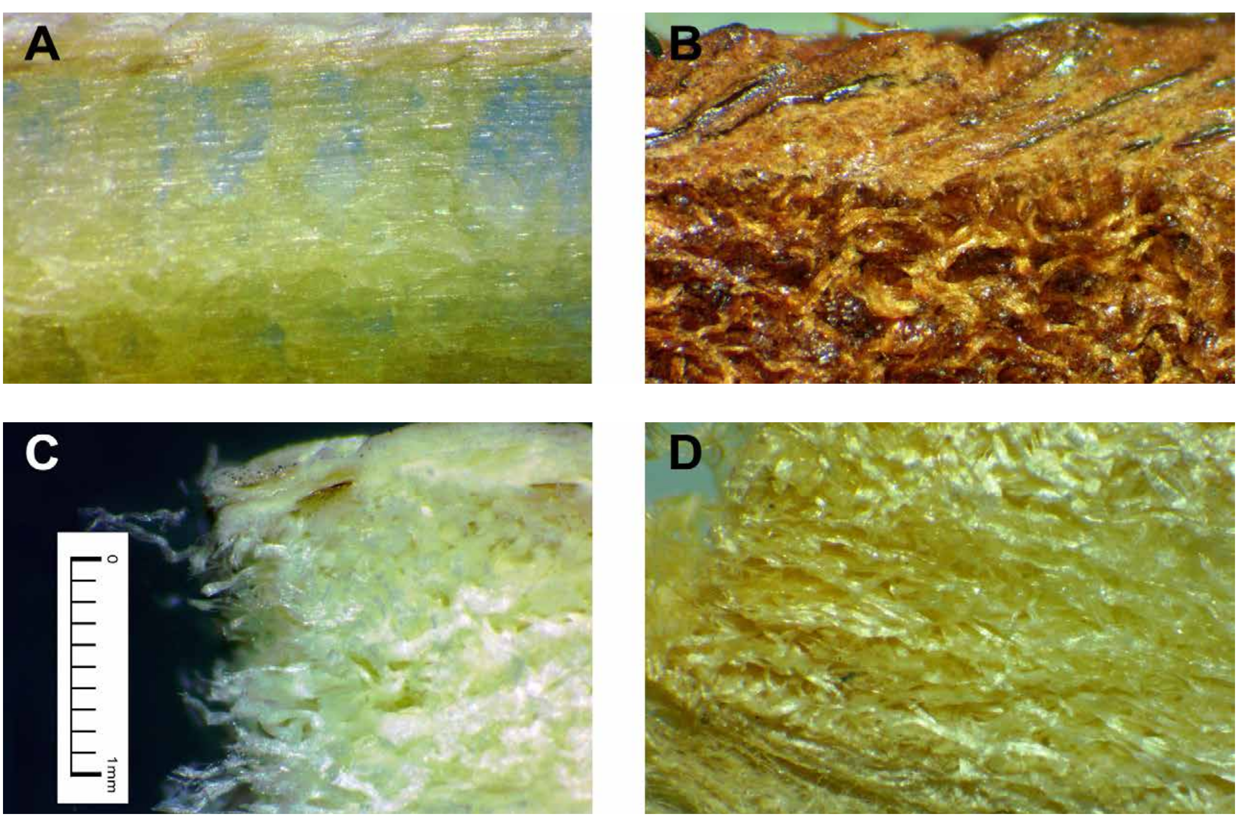


Fig. 5.4-5 (above). Appearance of Fibre Structure- **A**: Straight fibres, **B**: Large curves, **C**: Small curves, **D**: Crinkled fibres, Bottom middle: Disordered structure. Original magnification 40x, Scale = 1 mm, Bottom light.

Fig. 5.4-6 (opposite page above). Angle of Weave- **A**: Flat/Horizontal weave- Boot sole (Cow 20x), **B**: Low angle- (Red Deer 30x), **C** Medium angle- (Moose 20x), **D**: High angle- (Galloway Cow10x). Original magnification as listed, Scale = 1mm.

Fig. 5.4-7 (opposite page below). Compactness of Fibre Structure- **A**: Cemented structure, **B**: Very compact structure, **C**: Moderately compact structure, **D**: Loose/Airy structure. Original magnification 40x, Scale = 1 mm.


A
0
1mm
B
0
1mm
C
0
1mm
D
0
1mm


A
B
C
0
1mm
D

Cross Section Analysis Data Tables

Species	Fibre Size	Fullness	Angle of Weave	Splitting Up	Compactness	Fibre Appearance
American Bison *Bison bison*	Very Large	Moderate	Medium	Little	Moderately Compact	Small Curves
Galloway Cow *Bos taurus*	Large	Moderate	High	Little	Very Compact	Small Curves
Moose *Alces alces*	Medium	Moderate	Medium	Moderate	Moderately Compact	Crinkle
Red Deer *Cervus elaphus*	Medium	Moderate	Medium	Moderate	Moderately Compact	Small Curves with Crinkle
Reindeer/Caribou *Rangifer tarandus*	Fine	Moderate	Medium	Moderate	Moderately Compact	Large Curves
Soay Sheep *Ovis aries*	Fine	Moderate	Low	Little	Moderately Compact	Small Curves
Toggenburg Goat *Capra aegagrus hircus*	Fine	Moderate	High	Little	Moderately Compact	Large Curves

Figure 5.4-8. Alum Taw Cross Section Analysis.

Species	Fibre Size	Fullness	Angle of Weave	Splitting Up	Compactness	Fibre Appearance
American Bison *Bison bison*	Very Large	Full	Medium	Little	Very Compact	Small Curves
Galloway Cow *Bos taurus*	Large	Full	High	Little	Very Compact	Small Curves
Moose *Alces alces*	Medium	Full	Medium	Little	Moderately Compact	Small Curves
Red Deer *Cervus elaphus*	Medium	Full	Low	Little	Moderately Compact	Small Curves
Reindeer/Caribou *Rangifer tarandus*	Fine	Full	Low	Little	Very Compact	Small Curves
Soay Sheep *Ovis aries*	Fine	Full	Medium	Little	Moderately Compact	Large Curves
Toggenburg Goat *Capra aegagrus hircus*	Fine	Full	Medium	Little	Very Compact	Small Curves

Figure 5.4-9. Vegetable Tan Cross Section Analysis.

Species	Fibre Size	Fullness	Angle of Weave	Splitting Up	Compactness	Fibre Appearance
American Bison *Bison bison*	Very Large	Flat	Medium	Moderate	Loose/Airy	Large Curves
Galloway Cow *Bos taurus*	Large	Flat	Low	Moderate	Loose/Airy	Straight
Moose *Alces alces*	Medium	Flat	Low	Moderate	Moderately Compact	Large Curves
Red Deer *Cervus elaphus*	Medium	Flat	Medium	Moderate	Loose/Airy	Straight
Reindeer/Caribou *Rangifer tarandus*	Fine	Flat	Medium	Moderate	Loose/Airy	Straight
Soay Sheep *Ovis aries*	Fine	Flat	Medium	Finely	Loose/Airy	Straight
Toggenburg Goat *Capra aegagrus hircus*	Fine	Flat	Medium	Moderate	Loose/Airy	Straight

Figure 5.4-10. Dry Scrape Brain Tan Cross Section Analysis.

Species	Fibre Size	Fullness	Angle of Weave	Splitting Up	Compactness	Fibre Appearance
American Bison *Bison bison*	Very Large	Flat	Low	Little	Moderate	Disordered
Galloway Cow *Bos taurus*	Large	Flat	Low	Little	Very Compact	Small Curves
Moose *Alces alces*	Medium	Flat	Low	Little	Very Compact	Small Curves with Crinkle
Red Deer *Cervus elaphus*	Medium	Flat	Medium	Little	Loose/Airy	Straight
Reindeer/Caribou *Rangifer tarandus*	Fine	Flat	Medium	Little	Loose/Airy	Straight
Soay Sheep *Ovis aries*	Fine	Flat	Medium	Moderate	Loose/Airy	Straight
Toggenburg Goat *Capra aegagrus hircus*	Fine	Flat	Medium	Moderate	Loose/Airy	Straight

Figure 5.4-11. Urine Tan Cross Section Analysis.

Species	Fibre Size	Fullness	Angle of Weave	Splitting Up	Compactness	Fibre Appearance
American Bison *Bison bison*	Very Large	Flat	Low	None	Cemented	Small curves
Galloway Cow *Bos taurus*	Large	Flat	Horizontal	None	Cemented	Small curves
Moose *Alces alces*	Not Visible	Not Visible	Horizontal	None	Cemented	Not Visible
Red Deer *Cervus elaphus*	Not Visible	Not Visible	Horizontal	None	Cemented	Not Visible
Reindeer/Caribou *Rangifer tarandus*	Not Visible	Not Visible	Horizontal	None	Cemented	Not Visible
Soay Sheep *Ovis aries*	Not Visible	Not Visible	Horizontal	None	Cemented	Not Visible
Toggenburg Goat *Capra aegagrus hircus*	Not Visible	Not Visible	Horizontal	None	Cemented	Not Visible

Figure 5.4-12. Rawhide Cross Section Analysis.

Species	Fibre Size	Fullness	Angle of Weave	Splitting Up	Compactness	Fibre Appearance
American Bison *Bison bison*	Very Large	Flat	Low	Moderate	Very Compact	Small Curves
Galloway Cow *Bos taurus*	Large	Moderate	Low	Moderate	Very Compact	Small Curves
Moose *Alces alces*	Medium	Flat	Medium	Moderate	Loose/Airy	Straight
Red Deer *Cervus elaphus*	Medium	Moderate	Medium	Moderate	Loose/Airy	Straight
Reindeer/Caribou *Rangifer tarandus*	Fine	Flat	Medium	Finely	Loose/Airy	Straight
Soay Sheep *Ovis aries*	Fine	Flat	Medium	Moderate	Loose/Airy	Straight
Toggenburg Goat *Capra aegagrus hircus*	Fine	Flat	Medium	Moderate	Loose/Airy	Straight

Figure 5.4-13. Wet Scrape Brain Tan Cross Section Analysis.

5.5 Individual Fibre Analysis

Individual fibres for each of the different tannage types were taken from two species, Bison and Toggenburg goat, and mounted on slides for observation. Rawhide was excluded from this analysis as the cemented state of the fibres made it impossible to remove single fibres. The fibres were taken from the middle portion of the dermal thickness from each of the five tannages in an attempt to keep the fibre size comparable between them.

It was uncertain as to whether or not analysis of individual fibres would yield any unique data, compared to what had already been gathered. With this in mind, two contrasting species were chosen for this analysis, as they were a good representation of the variation seen between species across the sample collection. They have very different skins, opposite in many ways. Bison has large fibres, a loose fibre structure and is very thick; whereas the Toggenburg has fine fibres, a tight fibre structure and is relatively thin skinned. The fibre's general appearance was recorded by noting the size, outline, surface texture, lustre, translucence, fullness and splitting up for each tannage type. Splitting up and fullness have been previously covered and can be seen in Figure. 5.4-3 and 4 and Figure. 5.4-1 and 2 respectively. For the explanation on translucence see the macroscopic analysis section 5.2 and Figure. 5.2-8.

Fibre Size

As the technology to microscopically measure fibre size had become available in the department toward the end of this research, it was felt that, in addition to the qualitative size data, measurement of the individual fibres from the representative species would be of value. The two species individual fibres were measured in an effort to support the finding from the ordinal observations. The measurements were taken using an Axio Vision SE64 camera, mounted on an Olympus BX60F5 stereoscopic microscope. Four photographs were taken of fibres from each tannage type, for each species. Two measurements were taken for each photograph and the results used to create an average fibre thickness for each tannage type.

Outline

The outline of the individual fibres was given a designation of 'straight', 'undulations', and 'crinkled', as these categories covered the variation seen in the ten sample fibres. Fig. 5.5-1 illustrates these classifications.

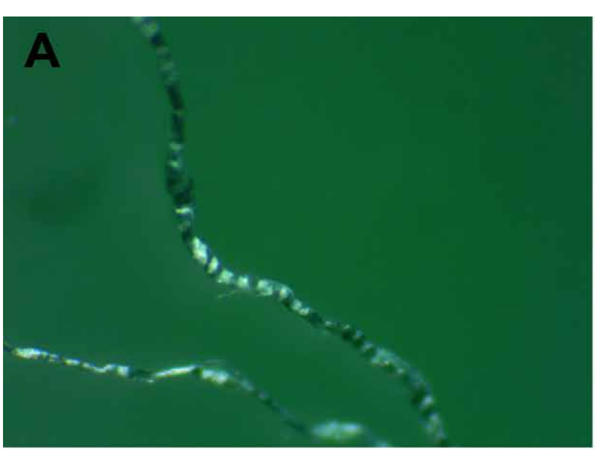
Surface Texture

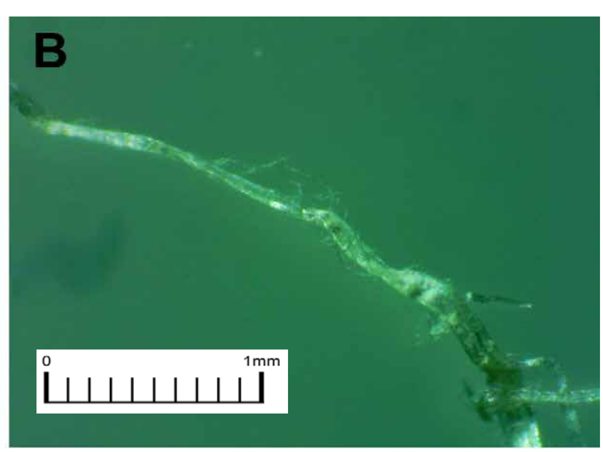
With such a small sample size, defining a broad set of surface texture distinctions was not useful for comparative purposes. In light of this, only two designations were used; 'textured' and 'smooth', which are shown in Figure. 5.5-2.

Lustre

This designation describes the way in which the different fibres reflect light. 'Shiny/Reflective', 'Sheen' and 'Dull Lustre' were used to describe the variation observed, with most samples falling into one end of the scale or the other. Shiny/Reflective describes the mirror like quality seen in many of the fibres, whereas a Dull Lustre describes fibres which, while they do reflect light, do so in a muted way. Sheen refers to a few fibres which fall in between these two designations, and which reflect light in a brighter way than Dull Lustre describes but are less intensely reflective than the Shiny designation describes. This attribute is illustrated alongside surface texture in Figure. 5.5-2.

Individual Fibre Analysis Photographs





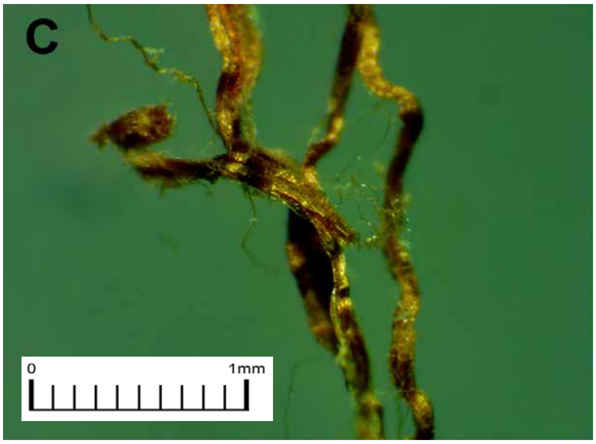


Figure 5.5-1. Outline of Individual Fibres- **A**: Crinkled, **B**: Straight, **C**: Undulations. Species: Bison, Original magnification 40x, Scale = 1 mm.

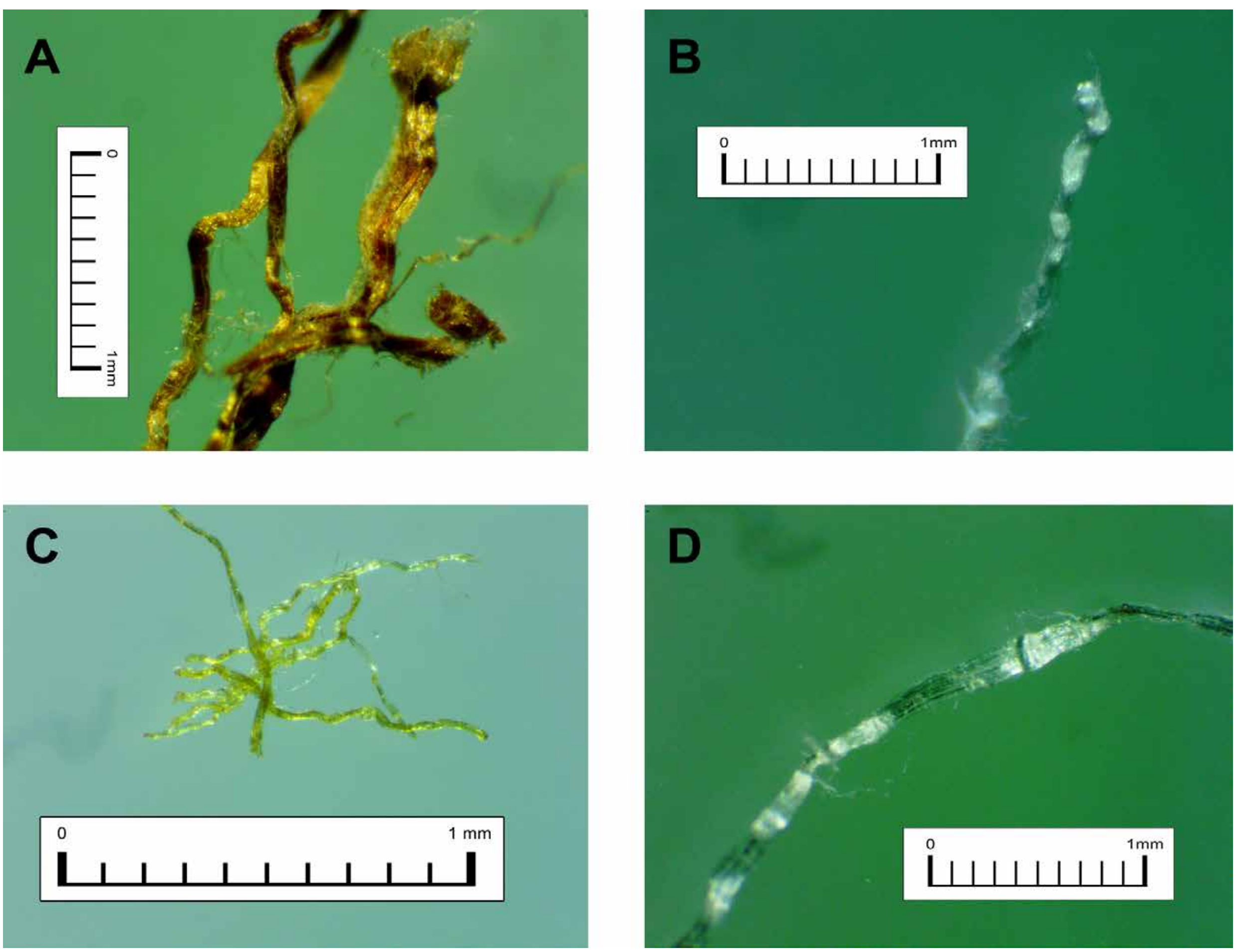


Figure 5.5-2. Surface Texture and Lustre- **A** and **B:** Dull lustre with Textured surface (Bison 40x: left-bark tan, right-alum taw), **C**: Sheen with Textured surface (Toggenburg 80x: bark tan), **D**: Shiny/Reflective with a Smooth surface (Bison 40x: Dry Scrape Brain Tan). Original magnification 40x, Scale = 1 mm.

Individual Fibre Analysis

Species	Avg. Size	Outline	Surface Texture	Lustre	Translucence	Fullness	Splitting Up
Wet Scrape Brain Tan							
American Bison *Bison bison*	122.82 μm	Straight	Smooth	Shiny Reflective	Yes	Flat	Moderate
Toggenburg Goat *Capra aegagrus hircus*	46.41 μm	Straight	Smooth	Shiny Reflective	Yes	Flat	Fine
Urine Tan							
American Bison *Bison bison*	116.42 μm	Straight	Smooth	Shiny Reflective	Yes	Flat	Moderate
Toggenburg Goat *Capra aegagrus hircus*	38.09 μm	Straight	Smooth	Shiny Reflective	Yes	Flat	Fine
Dry Scrape Brain Tan							
American Bison *Bison bison*	86.44 μm	Straight	Smooth	Shiny Reflective	Yes	Flat	Fine
Toggenburg Goat *Capra aegagrus hircus*	39.55 μm	Straight	Smooth	Shiny Reflective	Yes	Flat	Moderate
Vegetable Tan							
American Bison *Bison bison*	149.12 μm	Undulations	Textured	Dull Lustre	No	Full	Moderate
Toggenburg Goat *Capra aegagrus hircus*	49.56 μm	Undulations	Textured	Sheen	Slightly	Full	Little
Alum Taw							
American Bison *Bison bison*	116.02 μm	Crinkle	Textured	Dull Lustre	Yes	Moderate	Little
Toggenburg Goat *Capra aegagrus hircus*	62.71 μm	Crinkle	Textured	Sheen	Yes	Moderate	Little

Figure 5.5-3. Individual Fibre Analysis Table.

The above criteria have been consolidated into a tabular form and are presented in Figure. 5.5-3.

5.6 Conclusion

This analysis of the comparative sample collection, has established that the various tannage types, do possess traits which are individual to each tannage type. These traits are present when observing surface, cross section and individual fibres at both macro and microscopic levels. Chapter 5 sought to explain the analysis criteria and procedure, as well as describe the identifiable differences between tannage types. This was accomplished both with written descriptions and visually, using tables and photographs. In chapter 6, the data set generated by this process, will be presented by tannage type, in an effort to interpret the results in a meaningful way, for use in the analysis of museum collections of processed skin artefacts.

Chapter 6

Sample Collection Analysis by Tannage Type. Interpretation of Results

6.1 Introduction

Following on from the presentation of characteristics and explanation of analysis methodology in chapter 5, chapter 6 assesses the data by tannage type. This discussion is made up of four sections, which lay out features which characterise each tannage type on a criterion by criterion basis, starting with the most obvious macroscopic differences and working through to the more subtle microscopic features. Included in the discussion are hypotheses or explanations, detailing the formation of some of the tannage specific characteristics.

6.2 Macroscopic Characteristics

When the experimental sample collection is viewed as an entire set, a few very notable differences stand out. The first is the range of colours across the collection; the second is the variety of surface textures. In addition to these visually engaging attributes the tactile variety of the collection is notable. When the various samples are handled, the remarkable differences in pliability, stretch and thickness between the samples are all very apparent. Upon closer inspection of the surfaces of the samples in the collection, minor differences such as, more or less fibre rolls, or the presences of membrane remnants can be appreciated.

Colour

The variety of colours present in the sample collection is striking. They are the first visible attribute to catch the eye and are closely tied to the different tannage types. Dry and wet scrape brain tan were all varieties of cream in colour when removed from the tanning solutions and softened. The samples remain this colour unless they are smoked, in which case they can acquire a range of colours depending on the material used to produce the smoke and the temperature of the smoke. These colours can range from a light grey, through every shade of tan to a dark golden brown. The darkest shades the author has seen come from smoking with punky (partially rotten) Douglas fir (*Pseudotsuga menziesii*) wood; some of the lightest come from using various poplar species (*Populus sp.*). Though still needing proper scientific investigation, based on the author and other tanners' observations the temperature of the smoke also appears to affect the resulting colour.

Urine tan, while falling within the cream range with the other fat tans, often had a yellowish tinge to the sample most apparent on the grain side.

Alum taw was bright white when first removed from its tanning bath. The application of egg yolks as the fat liquoring agent gave the flesh sides of a few samples a similar yellow colouration. It did not, however, colour the grain sides. The white colourations of a few of the samples (Elk, Moose, and goat) were compromised during the fat liquoring process, and instead the finished samples' surfaces were cream with yellow to tan blotches where the alum had been unintentionally rinsed out.

Species	Hair	Alum Taw	Bark Tan	D.S. Brain Tan	W.S. Brain Tan	Urine Tan	Rawhide
American Badger *Taxidea taxus*	On	Cream	Red Brown	Light Golden Tan	Golden Tan	Yellow	Cream and Yellow
Beaver *Castor canadensis*	On	Cream	Red Brown	Light Golden Tan	Golden Tan	Cream	Cream and Transparent
American Bison *Bison bison*	On	Cream	Dark Brown	Grey Tan	Grey Tan	NS	Cream and Yellow
American Bison *Bison bison*	Off	Grey-Yellow cast	Dark Brown	Golden Tan	Golden Tan	Yellow	Yellow
Big Horn Sheep *Ovis Canadensis*	Off	Cream	Red Brown	Cream	Cream	Cream	Yellow
Black Bear *Ursus americanus*	On	Cream	Red Brown	Golden Tan	Golden Tan	Cream	Cream and Transparent
Canadian Lynx *Lynx canadensis*	On	Cream	Red Brown	NS	Light Golden Tan	Cream	Yellow
American Elk *Cervus Canadensis*	Off	Cream	Light Brown	Golden Tan	Golden Tan	Cream	Cream
Exmoor Pony *Equus ferus caballus*	Off	Yellow Cast	Light Brown	Golden Tan	Light Golden Tan	Cream	Cream and Yellow
Fallow Deer *Dama dama*	Off	Cream	Red Brown	Cream	NS	Cream	Cream and Transparent
Galloway Cow *Bos taurus*	Off	Cream	Light Brown	Light Golden Tan	Grey Tan	Cream	Transparent
German Shepherd *Canis lupus familiaris*	On	Cream	Light Brown	Light Golden Tan	Golden Tan	Cream	Cream
Moose *Alces alces*	Off	Cream	Light Brown	Golden Tan	Golden Tan	Cream	Light Brown /Transparent
Mule Deer *Odocoileus hemionus*	Off	Cream	Light Brown	Golden Tan	Golden Tan	Cream	Cream and Transparent
Pronghorn Antelope *Antilocapra americana*	Off	Cream	Light Brown	Golden Tan	Golden Tan	Cream	Cream and Transparent
Rabbit *Sylvilagus sp*	On	Yellow Cast	Red Brown	Light Golden Tan	Light Golden Tan	Cream	Cream and Transparent
Red Deer *Cervus elaphus*	Off	Yellow Cast	Light Brown	Golden Tan	Golden Tan	Cream	Cream and Transparent
Red Fox *Vulpes vulpes*	On	Cream	Red Brown	Light Golden Tan	Golden Tan	Yellow	Cream
Reindeer/Caribou *Rangifer tarandus*	On	Cream	Light Brown	Golden Tan	Light Golden Tan		Cream
Reindeer/Caribou *Rangifer tarandus*	Off	Cream	Light Brown	Golden Tan	Golden Tan	Cream	Yellow and Transparent
Roe Deer *Capreolus capreolus*	Off	Yellow Cast	Light Brown	Golden Tan	Golden Tan	Cream	Cream and Transparent
Soay Sheep *Ovis aries*	On	Cream	Light Brown	Light Golden Tan	Light Golden Tan	Yellow	Dark Brown
Soay Sheep *Ovis aries*	Off	Cream	Light Brown	Golden Tan	Golden Tan	Cream	Cream and Transparent
Toggenburg Goat *Capra aegagrus hircus*	On	White	Red Brown	Light Golden Tan	NS	Cream	Light Brown /Transparent
Toggenburg Goat *Capra aegagrus hircus*	Off	Cream	Red Brown	Golden Tan	Golden Tan	Cream	Cream and Transparent
Wild Boar *Sus scrofa*	Off		Grey Brown	Golden Tan			

Figure 6.2-1. Colour- Flesh Side by Tannage Type. *NS = no sample.

Species	Hair	Alum Taw	Bark Tan	Urine Tan	Rawhide
American Badger *Taxidea taxus*	Off	Cream	Dark Brown	Yellow	Yellow
Beaver *Castor canadensis*	Off	White	Red Brown	Yellow with brown spots	Yellow
American Bison *Bison bison*	Off	Cream-Tan Spots	Red Brown	Cream	Yellow and Transparent
American Bison *Bison bison*	Off	White	Red Brown	Yellow	Cream and Yellow
Big Horn Sheep *Ovis Canadensis*	Off	White	Red Brown	Yellow	Cream and Transparent
Black Bear *Ursus americanus*	Off	Cream	Dark Brown	Cream	Transparent
Canadian Lynx *Lynx canadensis*	Off	Cream-Tan Spots	Red Brown/ Dark spots	Cream with brown spots	Light Brown /Transparent
American Elk *Cervus Canadensis*	Off	White	Light Brown/ Dark Spots	Yellow	Yellow
Exmoor Pony *Equus ferus caballus*	Off	Cream	Light Brown	Cream	Cream and Transparent
Fallow Deer *Dama dama*	Off	White	Red Brown	Yellow	Cream and Transparent
Galloway Cow *Bos taurus*	Off	Cream	Dark Brown	Cream	Transparent
German Shepherd *Canis lupus familiaris*	Off	White	Light Brown	Cream	Cream and Transparent
Moose *Alces alces*	Off	Cream-Tan Spots	Red Brown/ Dark spots	Cream with brown spots	Light Brown /Transparent
Mule Deer *Odocoileus hemionus*	Off	Cream-Yellow Cast	Dark Brown	Cream	Cream and Transparent
Pronghorn Antelope *Antilocapra americana*	Off	Cream	Brown	Cream	Cream and Transparent
Reindeer/Caribou *Rangifer tarandus*	Off	Cream	Red Brown	Yellow	Yellow and Transparent
Soay Sheep *Ovis aries*	Off	White	Light Brown	Yellow/ Grey	Light Brown Transparent

Figure 6.2-2. Colour- Grain Side by Tannage Type.

The samples tanned using oak bark were all much darker in colour than the other tannages. The range of browns taken on by different samples soaking in the same bark bath for a similar amount of time was interesting. The grain side of the bark tanned samples were almost always darker than the flesh sides.

Rawhide's defining characteristic was not so much the colour (which fell within the cream to yellowish range seen for the other fat tans), but the transparency seen in many of the samples. Often one could read lettering through the sample (Figure. 5-3). Species which had a darker epidermal layer, including Soay sheep, Big Horn sheep and Moose, dried to a light brown colour. For ease of comparison, the colour variations recorded for each sample are arranged by tannage type in Figure. 6.2-1 for the flesh side, and Figure. 6.2-2 for the grain side.

Surface Texture

The range of surface textures seen in the sample collection, especially those on the grain side, are due not so much to tannage type, but to choices about reductive strategies by the tanner. However, these choices do have implications for tannage type. These implications are discussed further under 'manufacturing sequence' in chapter 7. In light of this, the surface textures have been consolidated by tannage type, and presented in Figure. 6.2-3, which details the flesh side and Figure. 6.2-4, which details the grain side. Each surface texture designation has been replaced by a number, allowing some basic statistical analysis, and decreasing the difficulty in pattern recognition within the data sets.

The flesh side surface appears to have only slight correlation with tannage type and is instead more strongly influenced by the species being tanned. Species with larger fibres generally had more coarsely textured flesh sides than those with finer fibres. Alum taw showed a slightly coarser surface than the other tannages, and urine tan is slightly less coarse. Rawhide fell at both ends

Species	Hair	Alum Taw	Bark Tan	D.S. Brain Tan	W.S. Brain Tan	Urine Tan	Rawhide	Average Texture by Species
American Badger *Taxidea taxus*	On	7	6	6	7	6	6 – Greasy	**6.40**
Beaver *Castor canadensis*	On	7	5	4	5	5	6	**5.33**
American Bison *Bison bison*	On	5	4	5	5	NS	4	**4.60**
American Bison *Bison bison*	Off	4	5	5	5	5	6	**5.00**
Big Horn Sheep *Ovis Canadensis*	Off	5	4	5	4	4	6	**4.67**
Black Bear *Ursus americanus*	On	7	5	6	6	5	7	**6.00**
Canadian Lynx *Lynx canadensis*	On	6	5	NS	3	4	1	**3.80**
American Elk *Cervus Canadensis*	Off	4	4	4	5	3	6	**4.33**
Exmoor Pony *Equus ferus caballus*	Off	5	3	4	4	3	6	**4.17**
Fallow Deer *Dama dama*	Off	4	4	4	NS	4	6	**4.40**
Galloway Cow *Bos taurus*	Off	5	4	4	5	5	6	**4.83**
German Shepherd *Canis lupus familiaris*	On	6	6	4	4	6	7	**5.50**
Moose *Alces alces*	Off	5	5	5	5	5	2	**4.50**
Mule Deer *Odocoileus hemionus*	Off	3	4	4	5	3	6	**4.17**
Pronghorn Antelope *Antilocapra americana*	Off	3	3	5	4	3	6	**4.00**
Rabbit *Sylvilagus sp*	On	4	4	5	3	3	2	**3.50**
Red Deer *Cervus elaphus*	Off	5	5	5	5	5	2	**4.50**
Red Fox *Vulpes vulpes*	On	6	3	4	3	4	2 – Greasy	**4.00**
Reindeer/Caribou *Rangifer tarandus*	On	4	3	4	4	NS	1	**3.20**
Reindeer/Caribou *Rangifer tarandus*	Off	4	3	3	4	4	3	**3.50**
Roe Deer *Capreolus capreolus*	Off	6	3	4	3	4	1	**3.50**
Soay Sheep *Ovis aries*	On	3	3	4	4	4	1	**3.17**
Soay Sheep *Ovis aries*	Off	3	3	3	3	1	1	**2.34**
Toggenburg Goat *Capra aegagrus hircus*	On	4	5	4	NS	5	6 – Greasy	**4.50**
Toggenburg Goat *Capra aegagrus hircus*	Off	6	3	4	4	4	6	**4.50**
Wild Boar *Sus scrofa*	Off	NS	7	3	NS	NS	NS	**5.00**
Average Texture by Tannage Type		**4.84**	**4.19**	**4.32**	**4.35**	**4.13**	**4.18**	

1: **Smooth** 2: **Slightly Textured** 3: **Very Lightly Fuzzy** 4: **Lightly Fuzzy** 5: **Coarsely Fuzzy** 6: **Lightly Rough and Scratchy** 7: **Rough and Scratchy**

Figure 6.2-3. Surface Texture of the Flesh Side by Tannage Type. *NS = no sample.

of the range, showing a bimodal tendency, with only two samples having one of middle range, fuzzy designations. The vegetable tan, wet-scrape brain tan (here after shortened to WSBT), and dry-scrape brain tan (DSBT) samples all grouped very close to one another.

The grain side, as expected, showed a much stronger correlation between tannage type and surface texture. Alum taw had the most heavily textured surface followed closely by bark tan. Urine tan showed a flatter grain overall, with less topography than that produced by either alum or oak bark. Rawhide fell in the nearly smooth range for most of the samples, and both brain tans' averages were close to lightly fuzzy. Dry scrape was very slightly smoother than wet scrape. To further illustrate the differences in the grain side surface texture between the tannage types, images of the six tannages are shown side by side for comparison in Figure. 6.2-5 and Figure. 6.2-6.

6.2-5 shows a large fibred species (Bison) and 6.2-6 a finer fibred species (Mule deer). Two species are shown for comparison as the textural difference between the grain-on tannage types is subtler in the finer fibred skins.

Species	Hair	Alum Taw	Bark Tan	D.S. Brain Tan	W.S. Brain Tan	Urine Tan	Rawhide	Avg. by Species
American Bison *Bison bison*	Off	10	10	3	3	10	7	**7.17**
Big Horn Sheep *Ovis Canadensis*	Off	8	8	2	2	8	7	**5.83**
American Elk *Cervus Canadensis*	Off	10	10	2	2	10	7	**6.83**
Exmoor Pony *Equus ferus caballus*	Off	8	7	1	7	7	6	**6.00**
Fallow Deer *Dama dama*	Off	7	8	1	NS	8	6	**6.00**
Galloway Cow *Bos taurus*	Off	10	10	3	2	8	8	**6.83**
Moose *Alces alces*	Off	10	10	2	2	8	8	**6.67**
Mule Deer *Odocoileus virginianus*	Off	10	7	1	1	8	7	**5.67**
Pronghorn Antelope *Antilocapra americana*	Off	4	4	1	1	4	7	**3.50**
Red Deer *Cervus elaphus*	Off	9	10	4	2	10	8	**7.17**
Reindeer/Caribou *Rangifer tarandus*	Off	8	9	1	1	7	9	**5.83**
Roe Deer *Capreolus capreolus*	Off	8	7	1	1	8	8	**5.50**
Soay Sheep *Ovis aries*	Off	7	8	4	1	7	1	**4.67**
Toggenburg Goat *Capra aegagrus hircus*	Off	8	8	2	2	8	8	**6.00**
Wild Boar *Sus scrofa*	Off		10	5				**7.50**
Average Texture by Tannage Type		**8.36**	**8.40**	**2.20**	**2.08**	**7.93**	**6.93**	

1: **Very Lightly Fuzzy** 2: **Lightly Fuzzy** 3: **Coarsely Fuzzy** 4: **Lightly Rough and Scratchy** 5: **Rough and Scratchy** 6: **Very Smooth** 7: **Smooth** 8: **Slightly Textured**
9: **Moderately Textured** 10: **Heavily Textured**

Figure 6.2-4. Surface Texture Grain Side by Tannage Type, (Hair-Off Samples Only). *NS = no sample.

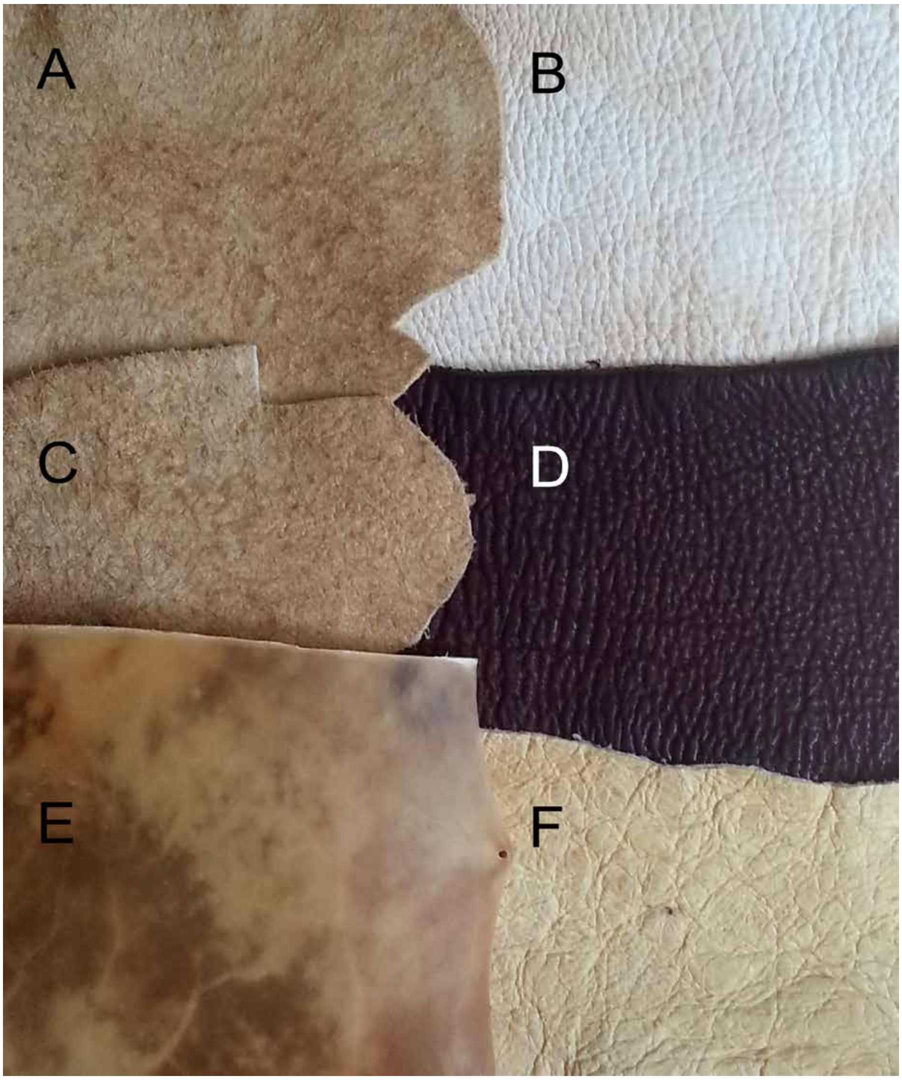


Figure 6.2-5. Grain Side Surface Textures by Tannage Type: **A**- DSBT, **B**- Alum taw, **C**- WSBT, **D**- Bark tan, **E**- Rawhide, **F**- Urine tan. Species: Bison, Original magnification 0x, Scale = 3 cm.

Handle

When handling the sample collection, the next attribute to stand out was the variety of thickness, drape and stretch felt between the samples. These characteristics combined are what this research refers to as 'handle'.

- The two brain tans were light, soft, stretchy, airy, lofty and (especially apparent in the thinner skins) draped in soft folds.
- The urine tan had a similar lightness, but with a bit more substance (denser feel), less stretch, and a stiffer drape and a flatter feel (little loft) than that of the grain-off fat tans.
- Alum taw was very stretchy but did not have the very light weight quality of the fat tans; it was denser, with a slightly tacky feel to the surface, likely caused by the salt that is part of the tanning bath. It draped very softly however, even though it had more substance than the fat tans.
- The vegetable tanned samples had much more substance than the other tans, giving them a dense feel. Even the very thin-skinned species had less stretch than samples from the same species tanned in other ways and draped in a more rounded way. Though the very thick vegetable tanned skins were assigned stiffer pliability ratings, none of the samples had the cardboard sound produced when some of the thicker/stiffer fat tanned skins were manipulated.
- The rawhide samples were all very stiff with no drape, and, depending on thickness, could feel like thin card stock paper through to a medium thickness piece of plywood.

It was apparent that handle differed by tannage type, however, measuring and presenting what is a very tactile attribute, proved challenging. Breaking 'handle' down into its constituent parts does not quite do justice to the differences in feel between the samples. However, it

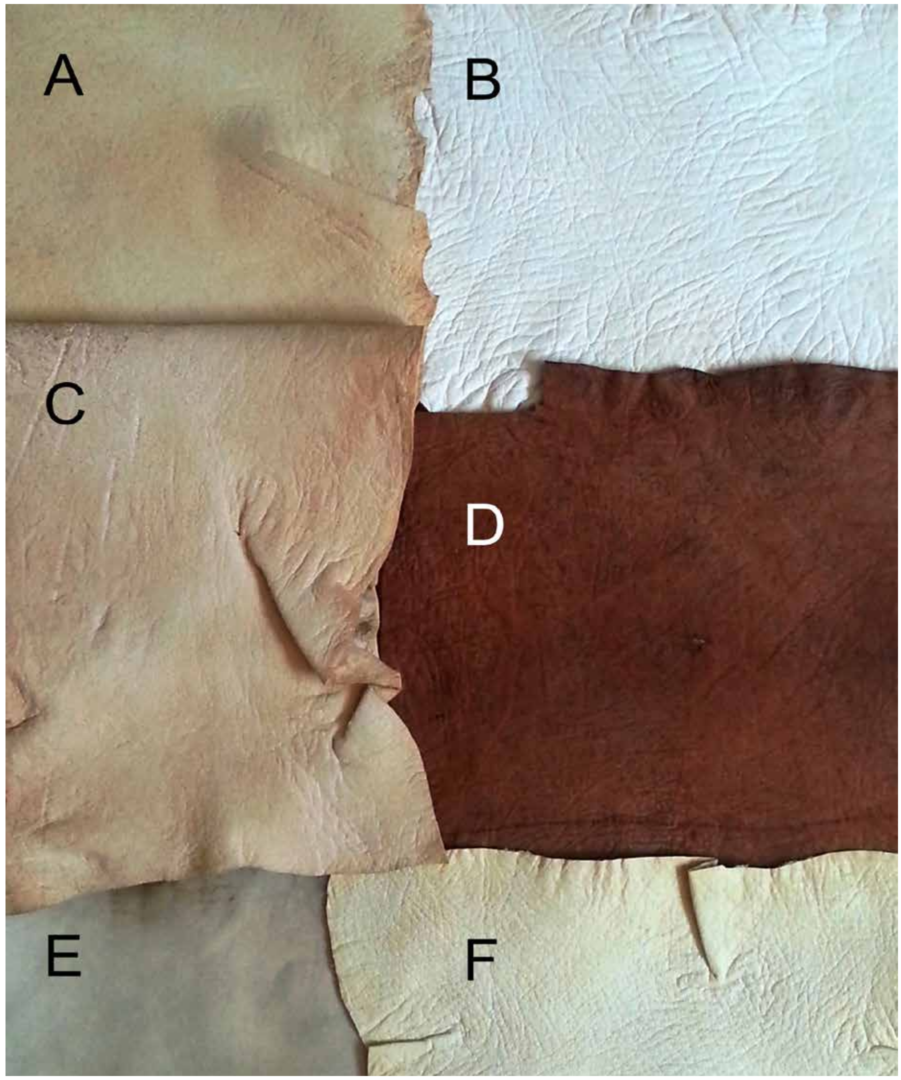


Figure 6.2-6. Grain Side Surface Textures by Tannage Type: **A**- DSBT, **B**- Alum taw, **C**- WSBT, **D**- Bark tan, **E**- Rawhide, **F**- Urine tan. Species: Mule Deer, Original magnification 0x, Scale = 3 cm.

does offer a way to qualify and to some degree quantify those differences. By assigning numerical designations to the range of variation for each of the following criteria, patterns which highlight the differences in handle are made easier to analyse.

Thickness

Variation in skin thickness by species was a known variable. That grain-off tannage types would be thinner than the grain-on tannages was expected as well. It was unknown how the grain-on tannages would relate to each other.

- The highest average thickness at (2.09 mm) across the collection was for the vegetable tanned samples. This tannage produces thicker skins due to the bonding of a significant amount of tannins to the collagen structure of the dermal fibres. This, in addition to coating the fibres' surfaces, making them more hydrophobic, forms cross links between the fibres, stabilising the fibre structure so little deflation or collapse occurs upon drying (Covington, 2011; Reed, 1972).
- Vegetable tan was followed by alum taw, which had the next highest average thickness (1.53 mm). Again, the addition of alum, which is slightly acidic and causes plumper fibres, and salt, which is added to control this acid plumping, contribute to a greater level of fibre network stability than that seen in the fat tans (Covington, 2011). The salt crystals also form as solids between the fibres as the skin dries lending additional support to the fibre network, serving a similar purpose to the tannin cross links above, though in a less permanent way, as the salt can be washed out if the skin is wetted (Haines, 1991c).
- The two brain tans were much thinner than the oak bark tanned samples with DSBT 0.72 mm thinner, and WSBT 0.98 mm thinner. The brain tanned samples were somewhat thinner than the alum taw at 0.16 thinner for DSBT and 0.42 mm for WSBT. It was

surprising however, to see the wet scrape brain tan's average thickness fall below that of dry scrape. It is commonly held that dry scraped brain tanned skins are generally thinner than wet scraped skins. This is due to the grain side being removed with a sharp tool which takes off a greater thickness of material than the wet scraping method. The thinness is exaggerated by the skin being softened in a frame, where the fibres remained stretched further apart than hand softening, allowing the fibres to pull together more closely and giving a loftier (usually thicker) end product. I believe this disparity may be partially due to the size of the samples. All of the dry scraped samples were removed from the frame and had the last bit of softening done by hand. Because of the small size of the samples, they were very difficult to soften in the frame, as the fibres could not be moved around sufficiently to prevent resticking. On average, the dry scraped samples were 0.26 mm thicker than the wet scraped skins. This cannot explain the belief, however, that a greater thickness of dermal tissue is removed by dry scraping. It maybe that this perceived thickness difference, is instead dependent on, and a product of, being softened in a frame, as opposed to a disparity in the amount of dermal thickness removed between the different de-graining methods. The amount of thickness removed by dry scraping can be controlled by the tanner in a way which is not replicable when wet scraping due to the use of blunt edged tools for the latter method. This means that the amount of removal done with a dry scraping tool can have more individual variation than that done with a wet scraping tool. Though, anything beyond the removal of the grain layer when dry scraping is usually referred to as 'thinning' not just de-graining the skin. It is in part this ability to thin a framed skin which makes this a popular and efficient method for working with large, thick skins.

- The urine tanned samples were also thinner than expected: 0.05 mm thinner on average than the rawhide samples, which were expected to form the bottom of the thickness range for tannage types. These samples were tanned with the grain layer intact, and it was therefore expected that they would be thicker than the de-grained brain tans. However, this was not the case, and with an average thickness of 0.94 mm this tannage had the lowest overall thickness. This may be in part due to the mild bacterial action seen in the urine bathes (as evidenced by fur slippage in some species), which disrupts the fibre network by further breaking down cross linkages between the collagen, which are already partially dissolved by soaking in the alkaline dehairing solutions (Thomson, 1991b). The samples had a deflated, flat look to both the grain surface and in cross section. As noted previously, however, the urine soak did add a perceived level of elasticity to the grain layer, not previously encountered by the author when producing grain-on fat tans using other methods.
- Lastly, the rawhide samples measured 0.99 mm as an average thickness making them the second thinnest average tannage type. The much greater amount of ground substance retained by rawhide over urine tan, and that the rawhide samples were dried under only light tension, may account for their slightly thicker average.
- To further visually illustrate the range of thicknesses between the tannage types, cross sections of Bison and Reindeer have been displayed in Figure. 6.2-7 and Figure. 6.2-8 with the tannage types laid out side by side for ease of comparison. Figure. 6.2-9 gives the range of thicknesses measured for each sample, and the average range of thickness by tannage type. The average thickness of each individual sample, and the average thickness of species and each tannage type, are presented in Figure. 6.2-10.

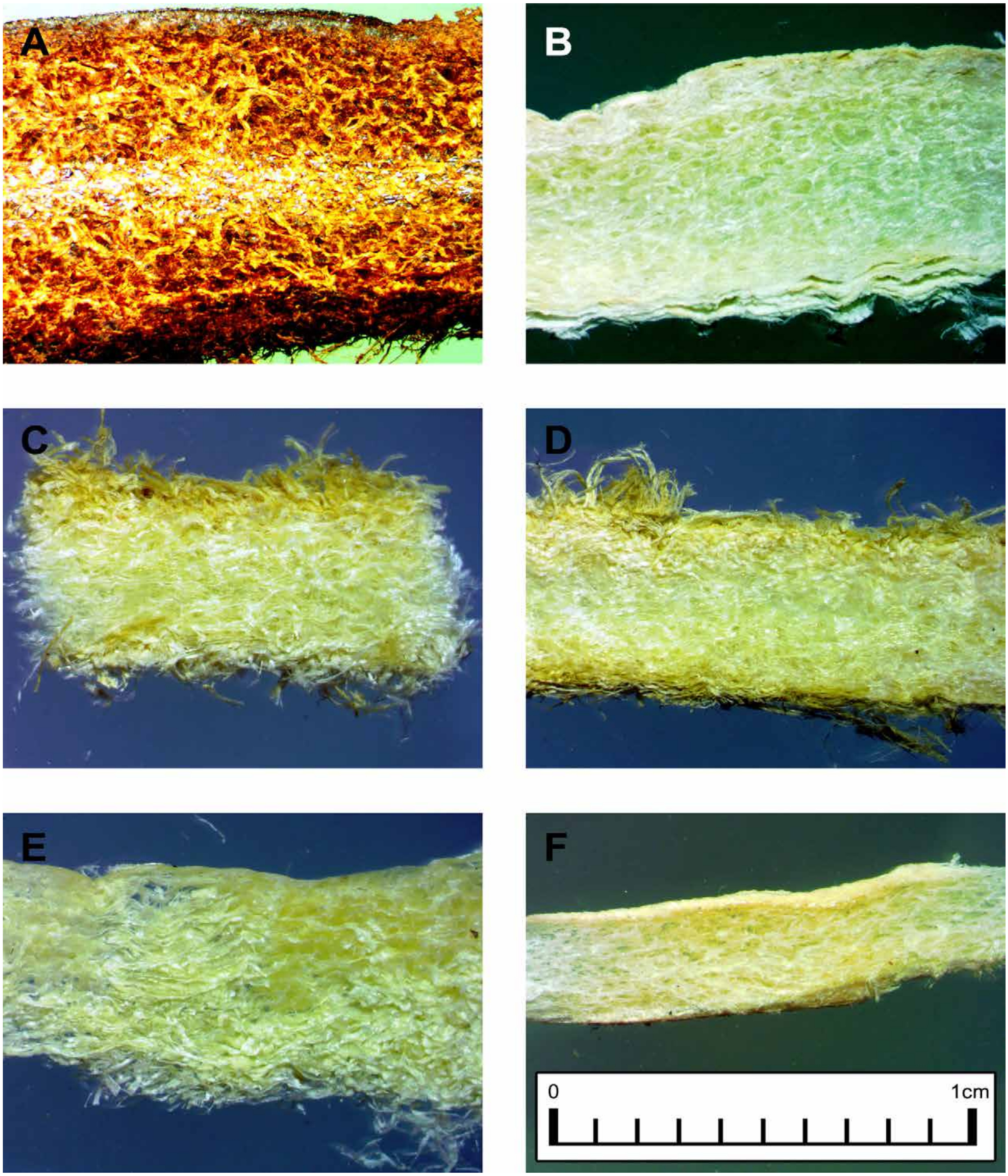


Figure 6.2-7. Thickness Range of Tannage Types: **A**- Bark tan, **B**- Alum taw, **C**- DSBT, **D**- WSBT, **E**- Urine tan, **F**- Rawhide. Species: Bison, Original magnification 10x, Scale = 1 cm.

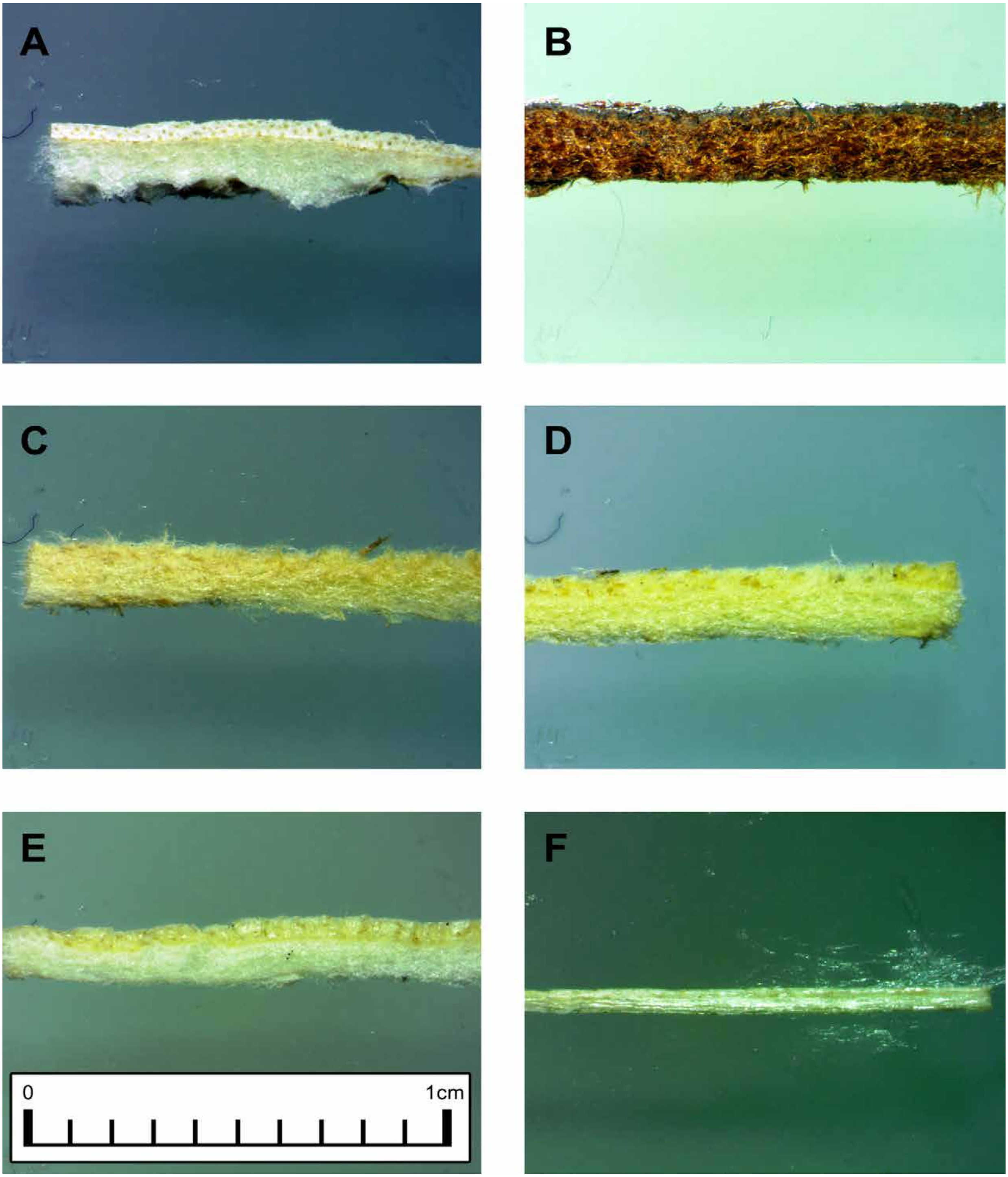


Figure 6.2-8. Thickness Range of Tannage Types: **A**- Bark tan, **B**- Alum taw, **C**- DSBT, **D**- WSBT, **E**- Urine tan, **F**- Rawhide. Species: Reindeer, Original magnification 10x, Scale = 1 cm.

Species	Fur	Alum Taw		Bark Tan		DSBT		WSBT		Urine Tan		Raw hide	
		Thin	Thick	Thin	Thick	Thin	Thick	Thin	Thick	Thin	Thick	Thin	Thick
American Badger *Taxidea taxus*	On	0.8	2.3	0.9	2	0.9	1.6	0.9	1.6	0.6	1.8	0.6	1.5
Beaver *Castor canadensis*	On	0.6	1.2	0.6	1.4	0.3	0.6	0.4	0.9	0.4	0.9	0.5	0.8
American Bison *Bison bison*	On	3.5	4.9	4	5.8	4.6	5.6	2.9	4.2	NS	NS	3.5	5
American Bison *Bison bison*	Off	2.3	4.7	7	8.3	3.8	4	3.5	5	2.5	4.2	2.8	3.8
Big Horn Sheep *Ovis Canadensis*	Off	1.4	1.9	1.1	2.2	1.1	1.4	0.6	1	0.7	1	1.6	1.9
Black Bear *Ursus americanus*	On	1	1.5	1	2	1.1	1.5	0.9	1.2	0.8	1.4	0.6	1.2
Canadian Lynx *Lynx canadensis*	On	0.9	1.2	0.6	1.3	NS	NS	0.2	0.4	0.2	0.5	0.1	0.2
American Elk *Cervus Canadensis*	Off	1.6	2.4	2.2	3.3	1.8	2.3	0.8	1.4	1	1.4	0.6	1.4
Exmoor Pony *Equus ferus caballus*	Off	0.5	1.2	0.8	1.3	0.4	0.8	0.5	0.7	0.3	0.5	0.2	0.3
Fallow Deer *Dama dama*	Off	0.6	1.7	0.9	1.3	0.9	1.3	NS	NS	0.5	0.9	0.2	0.3
Galloway Cow *Bos taurus*	Off	2.8	4.3	5.4	6.6	2	2.8	2.2	2.8	1.7	2.5	1.5	2.2
German Shepherd *Canis lupus familiaris*	On	0.6	1.3	0.7	1.7	0.5	0.7	0.5	0.9	0.5	0.8	0.5	0.9
Moose *Alces alces*	Off	2	3.4	3.4	4.7	1.9	2.4	1.5	2	1.2	1.7	1.3	2.4
Mule Deer *Odocoileus hemionus*	Off	0.8	1.1	0.8	1.5	0.9	1.1	0.8	1.1	0.3	0.6	0.3	0.4
Pronghorn Antelope *Antilocapra americana*	Off	0.4	0.7	0.8	1.1	0.8	1	0.6	1	0.3	0.5	0.3	0.4
Rabbit *Sylvilagus sp*	On	0.6	1.2	0.6	1.5	0.4	0.8	0.2	0.6	0.2	0.6	0.4	0.7
Red Deer *Cervus elaphus*	Off	1	1.6	1.7	2.7	1.4	1.6	0.8	1.7	0.9	1.8	0.4	0.6
Red Fox *Vulpes vulpes*	On	0.2	0.6	0.1	0.5	0.3	0.5	0.2	0.4	0.9	0.4	0.3	0.5
Reindeer/Caribou *Rangifer tarandus*	On	0.8	1.4	0.9	1.5	0.6	1.2	0.6	1.1	NS	NS	0.3	0.6
Reindeer/Caribou *Rangifer tarandus*	Off	0.7	1.2	1	1.5	0.5	0.9	0.6	1	0.6	0.9	0.5	0.8
Roe Deer *Capreolus capreolus*	Off	0.5	1.6	1.1	2.4	0.7	1	0.5	0.9	0.4	1	0.3	0.6
Soay Sheep *Ovis aries*	On	0.7	1.2	1	1.6	0.5	0.8	0.4	0.6	0.6	0.8	0.5	0.6
Soay Sheep *Ovis aries*	Off	0.6	1	0.8	1.4	0.3	0.6	0.3	0.5	0.4	0.7	0.4	0.6
Toggenburg Goat *Capra aegagrus hircus*	On	1.5	2.6	1.9	3	0.7	0.9	NS	NS	0.6	1.2	1	1.2
Toggenburg Goat *Capra aegagrus hircus*	Off	1.3	2.5	1.4	2.3	0.9	1.4	0.4	0.8	0.6	0.8	0.6	1.3
Wild Boar *Sus scrofa*	Off			1.4	2.9	1.6	2.6						
Average Range by Tannage Type		**1.11**	**1.95**	**1.62**	**2.53**	**1.16**	**1.58**	**0.88**	**1.38**	**0.70**	**1.17**	**0.77**	**1.21**

Figure 6.2-9. Range of Thickness for Each Sample in Millimetres. *NS = no sample.

Species	Hair	Alum Taw	Bark Tan	D.S. Brain Tan	W.S. Brain Tan	Urine Tan	Rawhide	Avg. by Species
American Badger *Taxidea taxus*	On	1.55	1.45	1.25	1.25	1.2	1.05	**1.29**
Beaver *Castor canadensis*	On	0.9	1	0.45	0.65	0.65	0.65	**0.72**
American Bison *Bison bison*	On	4.2	4.9	5.1	3.55		4.25	**4.40**
American Bison *Bison bison*	Off	3.5	7.65	3.9	4.25	3.35	3.3	**4.33**
Big Horn Sheep *Ovis Canadensis*	Off	1.65	1.65	1.25	0.8	0.85	1.75	**1.33**
Black Bear *Ursus americanus*	On	1.25	2	1.3	1.05	1.1	0.9	**1.27**
Canadian Lynx *Lynx canadensis*	On	1.05	0.95	NS	0.3	0.35	0.15	**0.56**
American Elk *Cervus Canadensis*	Off	2	2.75	2.05	1.1	1.2	1	**1.68**
Exmoor Pony *Equus ferus caballus*	Off	0.85	1.05	0.6	0.6	0.4	0.25	**0.63**
Fallow Deer *Dama dama*	Off	1.15	1.1	1.1		0.7	0.25	**0.86**
Galloway Cow *Bos taurus*	Off	3.55	6	2.4	2.5	2.1	1.85	**3.07**
German Shepherd *Canis lupus familiaris*	On	0.95	1.2	0.6	0.7	0.65	0.7	**0.80**
Moose *Alces alces*	Off	2.7	4.05	2.15	1.75	1.45	1.85	**2.33**
Mule Deer *Odocoileus hemionus*	Off	0.95	1.15	1	0.95	0.45	0.35	**0.81**
Pronghorn Antelope *Antilocapra americana*	Off	0.55	0.95	0.9	0.8	0.4	0.35	**0.66**
Rabbit *Sylvilagus sp*	On	0.9	1.05	0.6	0.4	0.4	0.55	**0.65**
Red Deer *Cervus elaphus*	Off	1.3	2.2	1.5	1.25	1.35	0.5	**1.35**
Red Fox *Vulpes vulpes*	On	0.4	0.3	0.4	0.3	0.65	0.4	**0.41**
Reindeer/Caribou *Rangifer tarandus*	On	1.1	1.2	0.9	0.85	NS	0.45	**0.90**
Reindeer/Caribou *Rangifer tarandus*	Off	0.95	1.25	0.7	0.35	0.75	0.65	**0.78**
Roe Deer *Capreolus capreolus*	Off	1.05	1.75	0.85	0.7	0.7	0.45	**0.92**
Soay Sheep *Ovis aries*	On	0.95	1.3	0.65	0.5	0.7	0.55	**0.78**
Soay Sheep *Ovis aries*	Off	0.8	1.1	0.45	0.4	0.55	0.5	**0.63**
Toggenburg Goat *Capra aegagrus hircus*	On	2.05	2.45	0.8		0.9	1.1	**1.46**
Toggenburg Goat *Capra aegagrus hircus*	Off	1.9	1.85	1.15	0.6	0.7	0.95	**1.19**
Wild Boar *Sus scrofa*	Off		2.15	2.1				**2.13**
Average Thickness by Tannage Type		**1.53**	**2.09**	**1.37**	**1.11**	**0.94**	**0.99**	

Figure 6.2-10. Average Thickness for Each Sample in Millimetres. *NS = no sample.

Pliability

Pliability, defined as the amount of flex and drape each sample possessed, is best discussed together with thickness, as thicker skins were, as a general rule, less pliable that thinner skins. That being said, the tannage type also affected the pliability of samples from the same species, and the averages of all the species by tannage type confirm this.

- The vegetable tanned samples were the stiffest (apart from rawhide), with an average pliability score of 2.19 which puts them as a group between pliable and flexible. This is in keeping with the tightening action which tannins have on the dermal tissue, compounded by the intact grain layer.
- Alum taw was more pliable, and as a group fell between soft and pliable, with its score of 1.68 placing it closer to the pliable end. Alum taw is a notably soft tannage type and has been a favourite of glove makers for its pliability and stretch (Covington, 2011).
- Of the two brain tans, DSBT was the stiffer of the two, with a score of 1.64, placing it slighter closer to the soft designation than alum taw. Wet scrape, as expected, was the most pliable, and as a group fell between very soft and soft, with a score of 0.96. Brain tans can become very soft due to the lack of the grain layer and the absence of ground substance within the dermal structure, along with the lightweight oils used to lubricate the fibre structure.
- Urine tan had a similar pliability rating as a group to alum taw and DSBT, falling between soft and pliable with a score of 1.68.
- Rawhide, with an average of 5.08, fell between hard and very hard, with most of the samples in the hard designation. This was expected and is due to the various mucous and non-collagenous proteins which make up the ground substance being left intact and in place, surrounding the dermal fibre matrix during the drying process.

The pliability ratings are detailed for each sample and averages shown for each species and each tannage type in Fig. 6.2-1-11.

When the samples with a thickness of 2 mm or greater are separated out from the thinner skins, the variation in the pliability showed a more definitive spread between the tannage types. Urine tan is more in line with expectations, being stiffer than the alum tawed samples, and DSBT more pliable than both alum taw and urine tan (Figure. 6.2-12). The samples over 2 mm in thickness (Figure. 6.2-13) show the same close averages between DSBT and urine tan, as seen in the averages of the combined thin and thick-skinned samples. The stiffer nature of the thick samples of DSBT and, to a lesser degree, WSBT, both are in part due to the size of the samples. The small samples were difficult to soften, as there was not enough purchase when holding onto them to be able to apply sufficient force to soften them thoroughly.

For a visual illustration of pliability, please see chapter 5, section 5, Figure. 5.2-9a through 5.2-9g.

Species	Hair	Alum Taw	Bark Tan	D.S. Brain Tan	W.S. Brain Tan	Urine Tan	Rawhide	Avg. by Species
American Badger *Taxidea taxus*	On	3	2	2	2	2	5	**2.67**
Beaver *Castor canadensis*	On	2	2	1	1	1	5	**2.00**
American Bison *Bison bison*	On	3	4	3	2	NS	6	**3.60**
American Bison *Bison bison*	Off	4	4	2	2	2	6	**3.33**
Big Horn Sheep *Ovis Canadensis*	Off	1	2	1	0	1	5	**1.67**
Black Bear *Ursus americanus*	On	3	2	3	2	3	5	**3.00**
Canadian Lynx *Lynx canadensis*	On	2	2	NS	1	0	4	**1.80**
American Elk *Cervus Canadensis*	Off	2	3	1	0	2	5	**2.17**
Exmoor Pony *Equus ferus caballus*	Off	1	2	2	0	1	5	**1.83**
Fallow Deer *Dama dama*	Off	1	2	2	NS	2	5	**2.40**
Galloway Cow *Bos taurus*	Off	4	4	4	4	4	6	**4.33**
German Shepherd *Canis lupus familiaris*	On	1	1	1	0	1	5	**1.50**
Moose *Alces alces*	Off	2	3	2	1	3	6	**2.83**
Mule Deer *Odocoileus hemionus*	Off	0	1	0	0	0	5	**1.00**
Pronghorn Antelope *Antilocapra americana*	Off	0	0	1	0	0	5	**1.00**
Rabbit *Sylvilagus sp*	On	2	2	2	2	3	5	**2.67**
Red Deer *Cervus elaphus*	Off	1	2	0	0	1	5	**1.50**
Red Fox *Vulpes vulpes*	On	0	1	1	0	1	4	**1.17**
Reindeer/Caribou *Rangifer tarandus*	On	2	2	2	2	NS	5	**2.60**
Reindeer/Caribou *Rangifer tarandus*	Off	1	2	1	1	2	5	**2.00**
Roe Deer *Capreolus capreolus*	Off	1	2	0	0	1	5	**1.50**
Soay Sheep *Ovis aries*	On	1	2	2	2	2	5	**2.30**
Soay Sheep *Ovis aries*	Off	1	2	1	0	1	5	**1.50**
Toggenburg Goat *Capra aegagrus hircus*	On	2	2	3	NS	4	5	**3.20**
Toggenburg Goat *Capra aegagrus hircus*	Off	2	2	0	0	2	5	**1.83**
Wild Boar *Sus scrofa*	Off		4	4				**4.00**
Average by Tannage Type		**1.68**	**2.19**	**1.64**	**0.96**	**1.70**	**5.08**	

0**: Very soft handle with lofty fibres, stretch in all directions and a limp drape.**
1: **Soft handle with moderate loft and stretch, and soft drape.**
2: **Pliable but with less loft, some stretch and a moderate drape.**
3: **Flexible but with little loft, little to no stretch, a stiff drape and (may have) a papery sound when rustled.**
4: **Moderate bendability with no loft, no stretch, a stiff drape and (may have) a cardboard sound when flexed.**
5: **Hard, cracks or splits when bent or permanently creases, no drape.**
6: **Very hard, no bendability but may flex slightly.**

Figure 6.2-11. Sample Pliability by Tannage Type. *NS = no sample.

Species	Hair	Alum Taw	Bark Tan	D.S. Brain Tan	W.S. Brain Tan	Urine Tan	Rawhide	Avg. by Species
American Badger *Taxidea taxus*	On	3	2	2	2	2	5	**2.67**
Beaver *Castor canadensis*	On	2	2	1	1	1	5	**2.00**
Big Horn Sheep *Ovis Canadensis*	Off	1	2	1	0	1	5	**1.67**
Black Bear *Ursus americanus*	On	3	2	3	2	3	5	**3.00**
Canadian Lynx *Lynx canadensis*	On	2	2	NS	1	0	4	**1.80**
American Elk *Cervus Canadensis*	Off	2	3	1	0	2	5	**2.17**
Exmoor Pony *Equus ferus caballus*	Off	1	2	2	0	1	5	**1.83**
Fallow Deer *Dama dama*	Off	1	2	2	NS	2	5	**2.40**
German Shepherd *Canis lupus familiaris*	On	1	1	1	0	1	5	**1.50**
Mule Deer *Odocoileus hemionus*	Off	0	1	0	0	0	5	**1.00**
Pronghorn Antelope *Antilocapra americana*	Off	0	0	1	0	0	5	**1.00**
Rabbit *Sylvilagus sp*	On	2	2	2	2	3	5	**2.67**
Red Deer *Cervus elaphus*	Off	1	2	0	0	1	5	**1.50**
Red Fox *Vulpes vulpes*	On	0	1	1	0	1	4	**1.17**
Reindeer/Caribou *Rangifer tarandus*	On	2	2	2	2	NS	5	**2.60**
Reindeer/Caribou *Rangifer tarandus*	Off	1	2	1	1	2	5	**2.00**
Roe Deer *Capreolus capreolus*	Off	1	2	0	0	1	5	**1.50**
Soay Sheep *Ovis aries*	On	1	2	2	2	2	5	**2.30**
Soay Sheep *Ovis aries*	Off	1	2	1	0	1	5	**1.50**
Toggenburg Goat *Capra aegagrus hircus*	On	2	2	3	NS	4	5	**3.20**
Toggenburg Goat *Capra aegagrus hircus*	Off	2	2	0	0	2	5	**1.83**
Average by Tannage Type		**1.38**	**1.81**	**1.30**	**0.68**	**1.50**	**4.90**	

0: **Very soft handle with lofty fibres, stretch in all directions and a limp drape.**
1: **Soft handle with moderate loft and stretch, and soft drape.**
2: **Pliable but with less loft, some stretch and a moderate drape.**
3: **Flexible but with little loft, little to no stretch, a stiff drape and (may have) a papery sound when rustled.**
4: **Moderate bendability with no loft, no stretch, a stiff drape and (may have) a cardboard sound when flexed.**
5: **Hard, cracks or splits when bent or permanently creases, no drape.**
6: **Very hard, no bendability but may flex slightly.**

Figure 6.2-12. Pliability of Skins Under 2mm Thick. *NS = no sample.

Species	Hair	Alum Taw	Bark Tan	D.S. Brain Tan	W.S. Brain Tan	Urine Tan	Rawhide	Avg. by Species
American Bison *Bison bison*	On	3	4	3	2	NS	6	**3.60**
American Bison *Bison bison*	Off	4	4	2	2	2	6	**3.33**
Galloway Cow *Bos taurus*	Off	4	4	4	4	4	6	**4.33**
Moose *Alces alces*	Off	2	3	2	1	3	6	**2.83**
Wild Boar *Sus scrofa*	Off	NS	4	4	NS	NS	NS	**4.00**
Average by Tannage Type		**3.25**	**3.80**	**3.00**	**2.25**	**3.00**	**6.00**	

0: **Very soft handle with lofty fibres, stretch in all directions and a limp drape.**
1: **Soft handle with moderate loft and stretch, and soft drape.**
2: **Pliable but with less loft, some stretch and a moderate drape.**
3: **Flexible but with little loft, little to no stretch, a stiff drape and (may have) a papery sound when rustled.**
4: **Moderate bendability with no loft, no stretch, a stiff drape and (may have) a cardboard sound when flexed.**
5: **Hard, cracks or splits when bent or permanently creases, no drape.**
6: **Very hard, no bendability but may flex slightly.**

Figure 6.2-13. Pliability of Skins Over 2mm Thick. *NS = no sample.

Stretch

As stressed previously in chapter 5, the difference in the amount of stretch between the tannage types is important, in that it affects their behaviour in response to stress from pulling. That being said, a distinction needs to be made regarding the definition of stretch. The 'static stretch' recorded for this section is the amount the sample gave when pulled from the corners, and then returned to its original shape. This should not be confused with 'potential stretch' which, for this research, refers to how much a piece of processed skin will stretch, when subjected to stress during daily use under differing conditions, such as wet or dry. The British Standards Draft for Development (Standards, 2006) uses the terms 'bagginess' and 'creep' to define similar behaviour in test samples. It is not known at present whether static stretch will correlate with potential stretch. It is suspected that it will not be directly representative, based on the static stretch scores for some of the stiffer brain tan samples being in the little to no stretch range – samples which, based on personal experience, have the potential to stretch quite drastically over time. Though the two definitions of stretch may not correlate well, the amount of static stretch did vary by tannage type, and so serves to highlight differences between the tannages.

- As expected, the vegetable tanned samples had the least amount of stretch, and with an average score of 1.77 fell between the designations of 'stretchy' and 'little stretch', being closer to little stretch than stretchy.
- Urine tan (1.57) was just behind the bark tanned samples, being 0.2 closer to the 'stretchy' designation than the 'little stretch' designation.
- Dry scrape brain was next and, with an average of 1.48, was .29 stretchier than the bark tanned samples.
- Alum taw was much stretchier than the vegetable tanned samples, and with an average of 1.08, fell only .08 away from the stretchy designation, with eight samples designated 'very stretchy'.
- Wet scrape brain tan's group average of 0.96 just below the stretchy designation, with nine samples being very stretchy.
- Rawhide, as a group, had no stretch whatsoever.

Though stretch is a very tactile quality, it is illustrated visually in chapter 5, Figure. 5.2-8a through 5.2-8d. The amount of stretch present in each sample, as well as the average stretch by species and average stretch by tannage type, are found in Figure. 6.2-14. Again, there is the trend for thicker skins to have less stretch than those from species with thinner skins.

Miscellaneous

The remaining criteria were less important in the analysis process and were simply noted as a matter of course. The presence or absence of fibre rolls (bundles of fibre which form on the flesh side) was recorded but appears to have little correlation to either species or tannage type. All skins which were softened formed fibre rolls, rawhide did not. Skins which were softened out of the frame by hand have a slightly higher tendency to form fibre rolls. The presence or absence of fibre rolls for each species, and the total number of samples with fibre rolls by tannage type, are presented in Figure. 6.2-15.

The presence of membrane remnants on the flesh side was also recorded. As mention in chapter 5, section 5, leaving an excessive amount of membrane can have

Species	Hair	Alum Taw	Bark Tan	D.S. Brain Tan	W.S. Brain Tan	Urine Tan	Rawhide	Avg. by Species
American Badger *Taxidea taxus*	On	2	2	2	2	2	3	**2.17**
Beaver *Castor canadensis*	On	2	1	2	2	2	3	**2.00**
American Bison *Bison bison*	On	2	3	3	2	NS	3	**2.60**
American Bison *Bison bison*	Off	3	3	2	2	2	3	**2.50**
Big Horn Sheep *Ovis Canadensis*	Off	0	2	1	1	1	3	**1.33**
Black Bear *Ursus americanus*	On	3	2	3	2	3	3	**2.67**
Canadian Lynx *Lynx canadensis*	On	1	1	NS	2	0	3	**1.40**
American Elk *Cervus Canadensis*	Off	1	2	1	0	2	3	**1.50**
Exmoor Pony *Equus ferus caballus*	Off	0	1	1	0	1	3	**1.00**
Fallow Deer *Dama dama*	Off	0	2	1	NS	2	3	**1.60**
Galloway Cow *Bos taurus*	Off	3	3	3	3	3	3	**3.00**
German Shepherd *Canis lupus familiaris*	On	1	0	1	0	1	3	**1.00**
Moose *Alces alces*	Off	1	3	2	1	3	3	**2.17**
Mule Deer *Odocoileus hemionus*	Off	0	1	0	0	0	3	**0.67**
Pronghorn Antelope *Antilocapra americana*	Off	0	0	1	0	0	3	**0.67**
Rabbit *Sylvilagus sp*	On	1	2	2	2	3	3	**2.17**
Red Deer *Cervus elaphus*	Off	0	1	0	0	1	3	**0.83**
Red Fox *Vulpes vulpes*	On	0	1	2	0	0	3	**1.00**
Reindeer/Caribou *Rangifer tarandus*	On	1	2	2	2	NS	3	**2.00**
Reindeer/Caribou *Rangifer tarandus*	Off	1	2	0	0	1	3	**1.17**
Roe Deer *Capreolus capreolus*	Off	0	2	0	0	1	3	**1.00**
Soay Sheep *Ovis aries*	On	1	2	1	1	2	3	**2.00**
Soay Sheep *Ovis aries*	Off	0	1	1	0	1	3	**1.00**
Toggenburg Goat *Capra aegagrus hircus*	On	2	2	3	NS	3	3	**2.60**
Toggenburg Goat *Capra aegagrus hircus*	Off	2	2	0	0	2	3	**1.50**
Wild Boar *Sus scrofa*	Off		3	3				**3.00**
Average by Tannage Type		**1.08**	**1.77**	**1.48**	**0.96**	**1.57**	**3.00**	
0: **Very Stretchy** 1: **Stretchy** 2: **Little Stretch** 3: **No Stretch**								

Figure 6.2-14. Amount of Static Stretch by Tannage Type. *NS = no sample.

consequences for the tanning process. All the skins used in the sample collection underwent the same de-fleshing process. Following this the steps during processing varied by tannage type. It is interesting, then, that there is a notable difference in the amount of membrane seen on the finished samples between the tannage types. Alum taw and bark tan had only three samples, each with a small amount of membrane remaining. The three fat tans had between seven and eight each, and, in the rawhide samples, all the samples were found to have a small amount of remaining membrane.

The rawhide is easily explainable as, after de-fleshing, the flesh side undergoes no further processing. Membrane remnants left on other tannages after de-fleshing have more chances to be removed, either during the process of squeezing out excess liquid over the beam, or by the often abrasive softening process. DSBT, after being laced into a frame, has both sides scraped with a sharp tool, and is then softened in a similar abrasive manner. This makes the presence of membrane remnants in the centre unlikely, though having them around the edges is almost assured, as the scraping and softening tools are less effective near the edges. The closer the tools are taken to the edge, the greater the chance of creating holes becomes. However, the bark tan, alum taw, urine tan and WSBT samples were all worked over the tanning beam multiple times during the process and were softened in a similar fashion. The different amount of membrane remnants seen between the two fat tans and the bark and alum taw samples is surprising and at present no explanation is forthcoming. The reindeer samples could potentially skew this result somewhat as the membrane proved impossible to remove completely from the many bot fly scars present on the skin. The presence or absence of membrane remnants on the flesh side for each sample, and the total number of samples with noticeable membrane remnants by species and by tannage type, are recorded in Figure. 6.2-16.

Species	Hair	Alum Taw	Bark Tan	D.S. Brain Tan	W.S. Brain Tan	Urine Tan	Rawhide
American Badger *Taxidea taxus*	On	1	1	1	1	1	1
Beaver *Castor canadensis*	On	1	1	1	1	1	0
American Bison *Bison bison*	On	1	1	1	1	NS	0
American Bison *Bison bison*	Off	1	1	1	1	1	0
Big Horn Sheep *Ovis Canadensis*	Off	1	1	1	1	1	0
Black Bear *Ursus americanus*	On	1	1	1	1	1	0
Canadian Lynx *Lynx canadensis*	On	1	1	NS	1	1	0
American Elk *Cervus Canadensis*	Off	1	1	1	1	1	0
Exmoor Pony *Equus ferus caballus*	Off	1	1	1	1	1	0
Fallow Deer *Dama dama*	Off	1	1	1	NS	1	0
Galloway Cow *Bos taurus*	Off	1	1	1	1	1	0
German Shepherd *Canis lupus familiaris*	On	0	1	0	1	1	1
Moose *Alces alces*	Off	1	1	1	1	1	0
Mule Deer *Odocoileus hemionus*	Off	1	1	0	1	0	0
Pronghorn Antelope *Antilocapra americana*	Off	1	1	1	1	1	0
Rabbit *Sylvilagus sp*	On	1	1	1	1	1	0
Red Deer *Cervus elaphus*	Off	1	1	1	1	1	0
Red Fox *Vulpes vulpes*	On	0	0	1	1	1	0
Reindeer/Caribou *Rangifer tarandus*	On	1	0	1	1	NS	0
Reindeer/Caribou *Rangifer tarandus*	Off	1	0	1	1	1	0
Roe Deer *Capreolus capreolus*	Off	1	1	1	1	1	0
Soay Sheep *Ovis aries*	On	0	0	0	0	0	0
Soay Sheep *Ovis aries*	Off	1	0	1	1	0	0
Toggenburg Goat *Capra aegagrus hircus*	On	1	1	0	NS	1	0
Toggenburg Goat *Capra aegagrus hircus*	Off	1	0	1	0	1	1
Wild Boar *Sus scrofa*	Off	NS	0	0	NS	NS	NS
Samples with Fibre Rolls		**22**	**19**	**20**	**21**	**20**	**3**
1: **Yes** 0: **No**							

Figure 6.2-15. Presence of Fibre Rolls by Tannage Type. *NS = no sample.

Species	Hair	Alum Taw	Bark Tan	D.S. Brain Tan	W.S. Brain Tan	Urine Tan	Rawhide	Samples with Membrane per Species
American Badger *Taxidea taxus*	On	0	0	0	0	0	1	**1**
Beaver *Castor canadensis*	On	0	0	0	0	0	1	**1**
American Bison *Bison bison*	On	0	0	0	1	NS	0	**1**
American Bison *Bison bison*	Off	0	0	0	0	0	1	**1**
Big Horn Sheep *Ovis Canadensis*	Off	0	0	0	0	1	1	**2**
Black Bear *Ursus americanus*	On	0	0	0	0	0	1	**1**
Canadian Lynx *Lynx canadensis*	On	0	0	NS	1	0	1	**2**
American Elk *Cervus Canadensis*	Off	0	0	0	0	1	1	**2**
Exmoor Pony *Equus ferus caballus*	Off	0	0	0	0	0	1	**1**
Fallow Deer *Dama dama*	Off	0	0	1	NS	0	1	**2**
Galloway Cow *Bos taurus*	Off	0	0	0	1	0	1	**2**
German Shepherd *Canis lupus familiaris*	On	0	0	0	0	0	1	**1**
Moose *Alces alces*	Off	0	0	1	0	0	1	**2**
Mule Deer *Odocoileus hemionus*	Off	0	0	1	0	0	0	**1**
Pronghorn Antelope *Antilocapra americana*	Off	0	0	0	1	0	1	**2**
Rabbit *Sylvilagus sp*	On	1	1	0	0	1	1	**4**
Red Deer *Cervus elaphus*	Off	0	0	1	1	1	1	**4**
Red Fox *Vulpes vulpes*	On	0	0	0	0	0	1	**1**
Reindeer/Caribou *Rangifer tarandus*	On	1	1	1	1	NS	1	**5**
Reindeer/Caribou *Rangifer tarandus*	Off	1	1	1	1	1	1	**6**
Roe Deer *Capreolus capreolus*	Off	0	0	1	1	1	1	**4**
Soay Sheep *Ovis aries*	On	0	0	0	0	0	0	**0**
Soay Sheep *Ovis aries*	Off	0	0	0	0	0	1	**1**
Toggenburg Goat *Capra aegagrus hircus*	On	0	0	0	NS	0	1	**1**
Toggenburg Goat *Capra aegagrus hircus*	Off	0	0	0	0	0	1	**1**
Wild Boar *Sus scrofa*	Off		0	0				**0**
Samples with Membrane per Tannage Type	**3**	**3**	**7**	**8**	**6**	**22**		
1: **Yes** 0: **No**								

Figure 6.2-16. Presence of Membrane Remnants by Tannage Type. *NS = no sample.

6.3 Light Translucence and Ultraviolet Light Reactivity

The ability of light to penetrate the full thickness of each sample, and each sample's reaction to UV light (both on the flesh and grain side surfaces and on a freshly cut edge) are strongly linked to tannage type.

Light Translucence

As detailed in chapter 5, section 5.2, the vegetable tanned samples did not allow visible light to pass through the samples. The only exception to this was the oak bark tanned rabbit skin, through which, when it was placed over a flashlight (torch) in a fully darkened room, a very dim glow was visible. All the tannages apart from bark tan, allowed visible light to pass through the skin. In a few cases with thicker skinned species or those with a darker epidermis, the light translucence was only visible in a dim or darkened room. All of the samples which fell into this category had been alum tawed. The only variable aside from the presence of tannins which affected translucence at all was the colouration acquired from smoking the two varieties of brain tan. In areas which had been coloured more darkly during smoking, the light shone more dimly through these darker pigmented areas but was still clearly visible. The light translucency of each sample, and the total number of samples with translucence by tannage type are summarised in Figure. 6.3-1. This trait is visually illustrated in Figure. 5.2-7a through 5.2-7c in chapter 5.

Ultraviolet Light Reactivity: Surfaces

The response of the flesh and grain side surfaces to UV light had much the same result as the light translucency. All samples from all tannages, apart from those which had been vegetable tanned, glowed under UV light. However, there was a difference in intensity of the reactions to UV. In light of this, instead of using a yes or no scale, three classifications of reactivity were opted for: 'none', 'moderate' and 'strong', were recorded for each sample exposed to UV light. As with translucency, the smoking of the two brain tan types resulted in a more muted reaction when the surfaces are exposed to UV. Alum taw, urine tan and rawhide all showed uniformly strong reactions, while the DSBT and WSBT showed mostly moderate reactions. Oak bark tanned samples unanimously showed no reaction. A few brain tanned samples glowed strongly as opposed to moderately. These were tanned late in the research and had not been smoked. This strongly supports the hypothesis that the dimming effect seen on the other brain tan samples results from the smoking process. There was no correlation between UV reactions and species. The flesh and grain side surface reactions to UV light for each sample, and the average UV reactivity by tannage type, are detailed in Figure. 6.3-2.

Ultraviolet Light Reactivity: Freshly Cut Edge

When the freshly cut edge of each sample was exposed to UV light, it became apparent that not all the vegetable tanned samples had tannin penetration through the total dermal thickness. The samples were removed from the oak bark solution when the colour was visible through the centre of the dermal thickness, as determined by cutting a fresh section off the thickest edge every few days to check the progress. It was not surprising to see some level of interior reaction from the very thick Bison samples, but some of the thinner-skinned species also fluorescing were unexpected. The hair-off Toggenburg goat sample, as well as the Big Horn Sheep and American Badger vegetable tans all showed interior stripes which fluoresced under UV. Badger is often a greasy skin, and as the fur was left on this sample it was not put into the alkaline solution (which, in addition causing the hair to slip, also degreases the skin thoroughly). It is possible that this inhibited the tannins from fully penetrating this sample. Though both the Big Horn and Toggenburg have a tight fibre structure, neither are particularly thick skins. Though it may be coincidental, it is interesting that both samples which resisted tannin penetration are both ovicaprids.

Alum taw, urine tan and rawhide continued to show strong reactions to UV, and the freshly cut edge reactions of these tans matched the surface reactions. However, the interior of the dry scrape and wet scrape brain tan samples showed a much stronger reaction to UV than their surfaces. This further supports the theory that it is the addition of smoke which dimmed the surface reactions of most DSBT and WSBT samples. Two exceptions to this were DSBT Roe Deer and hair-off Toggenburg samples, with had a moderate interior reaction to UV light, similar to their surface fluorescence. The Roe Deer sample has a very thin skin with a very open/airy fibre structure. Therefore, logic suggests that the smoke simply penetrated further through the dermal thickness than with the other skins. There is no immediately apparent explanation for the Toggenburg sample's aberrant result. The UV reaction of a freshly cut edge for each sample, and the average UV reaction by tannage type are detailed in Figure. 6.3-3. Figure. 6.3-4 gives miscellaneous details related to light reactions which were noted for some samples. These are arranged by tannage type.

Species	Hair	Alum Taw	Bark Tan	D.S. Brain Tan	W.S. Brain Tan	Urine Tan	Rawhide	Misc.
American Badger *Taxidea taxus*	On	1	0	1	1	1	1	
Beaver *Castor canadensis*	On	1	0	1	1	1	1	
American Bison *Bison bison*	On	1	0	1	1	NS	1	In dim light Alum Taw
American Bison *Bison bison*	Off	1	0	1	1	1	1	In dark only Alum Taw
Big Horn Sheep *Ovis Canadensis*	Off	1	0	1	1	1	1	
Black Bear *Ursus americanus*	On	1	0	1	1	1	1	
Canadian Lynx *Lynx canadensis*	On	1	0	NS	1	1	1	
American Elk *Cervus Canadensis*	Off	1	0	1	1	1	1	
Exmoor Pony *Equus ferus caballus*	Off	1	0	1	1	1	1	
Fallow Deer *Dama dama*	Off	1	0	1	NS	1	1	
Galloway Cow *Bos taurus*	Off	1	0	1	1	1	1	In dim light Alum Taw
German Shepherd *Canis lupus familiaris*	On	1	0	1	1	1	1	
Moose *Alces alces*	Off	1	0	1	1	1	1	In dark only Alum Taw
Mule Deer *Odocoileus hemionus*	Off	1	0	1	1	1	1	
Pronghorn Antelope *Antilocapra americana*	Off	1	0	1	1	1	1	
Rabbit *Sylvilagus sp*	On	1	1	1	1	1	1	Minimal in dark Only, Bark Tan
Red Deer *Cervus elaphus*	Off	1	0	1	1	1	1	
Red Fox *Vulpes vulpes*	On	1	0	1	1	1	1	
Reindeer/Caribou *Rangifer tarandus*	On	1	0	1	1	NS	1	
Reindeer/Caribou *Rangifer tarandus*	Off	1	0	1	1	1	1	
Roe Deer *Capreolus capreolus*	Off	1	0	1	1	1	1	
Soay Sheep *Ovis aries*	On	1	0	1	1	1	1	
Soay Sheep *Ovis aries*	Off	1	0	1	1	1	1	
Toggenburg Goat *Capra aegagrus hircus*	On	1	0	1	NS	1	1	
Toggenburg Goat *Capra aegagrus hircus*	Off	1	0	1	1	1	1	In dim light Alum Taw
Wild Boar *Sus scrofa*	Off	NS	0	1	NS	NS	NS	
Samples with Light Translucence by Tannage Type		**25**	**1**	**25**	**23**	**23**	**25**	
1: **Yes** 0: **No**								

Figure 6.3-1. Light Translucence of Samples by Tannage Type. *NS = no sample.

Species	Hair	Alum Taw	Bark Tan	D.S. Brain Tan	W.S. Brain Tan	Urine Tan	Rawhide	Average by Species
American Badger *Taxidea taxus*	On	3	1	2	2	3	3	**2.33**
Beaver *Castor canadensis*	On	3	1	2	2	3	3	**2.33**
American Bison *Bison bison*	On	3	1	2	2	NS	3	**2.20**
American Bison *Bison bison*	Off	3	1	2	2	3	3	**2.33**
Big Horn Sheep *Ovis Canadensis*	Off	3	1	3	3	3	3	**2.67**
Black Bear *Ursus americanus*	On	3	1	2	2	3	3	**2.33**
Canadian Lynx *Lynx canadensis*	On	3	1	NS	2	3	3	**2.40**
American Elk *Cervus Canadensis*	Off	3	1	2	2	3	3	**2.33**
Exmoor Pony *Equus ferus caballus*	Off	3	1	3	3	3	3	**2.67**
Fallow Deer *Dama dama*	Off	3	1	2	NS	3	3	**2.40**
Galloway Cow *Bos taurus*	Off	3	1	2	2	3	3	**2.33**
German Shepherd *Canis lupus familiaris*	On	3	1	2	2	3	3	**2.33**
Moose *Alces alces*	Off	3	1	2	2	3	3	**2.33**
Mule Deer *Odocoileus hemionus*	Off	3	1	2	2	3	3	**2.33**
Pronghorn Antelope *Antilocapra americana*	Off	3	1	2	2	3	3	**2.33**
Rabbit *Sylvilagus sp*	On	3	1	2	2	3	3	**2.33**
Red Deer *Cervus elaphus*	Off	3	1	2	2	3	3	**2.33**
Red Fox *Vulpes vulpes*	On	3	1	2	2	3	3	**2.33**
Reindeer/Caribou *Rangifer tarandus*	On	3	1	2	2	3	3	**2.33**
Reindeer/Caribou *Rangifer tarandus*	Off	3	1	2	2	3	3	**2.33**
Roe Deer *Capreolus capreolus*	Off	3	1	2	2	3	3	**2.33**
Soay Sheep *Ovis aries*	On	3	1	2	2	3	3	**2.33**
Soay Sheep *Ovis aries*	Off	3	1	2	2	3	3	**2.33**
Toggenburg Goat *Capra aegagrus hircus*	On	3	1	2	NS	3	3	**2.40**
Toggenburg Goat *Capra aegagrus hircus*	Off	3	1	2	2	3	3	**2.33**
Wild Boar *Sus scrofa*	Off		1	2				**1.50**
Average UV Reaction by Tannage Type		**3.00**	**1.00**	**2.08**	**2.09**	**3.00**	**3.00**	
1: **None** 2: **Moderate** 3: **Strong**								

Figure 6.3-2. Ultraviolet Light Reaction of Samples Surfaces by Tannage Type. *NS = no sample.

Species	Hair	Alum Taw	Bark Tan	D.S. Brain Tan	W.S. Brain Tan	Urine Tan	Rawhide
American Badger *Taxidea taxus*	On	4	2	4	4	4	4
Beaver *Castor canadensis*	On	4	1	4	4	4	4
American Bison *Bison bison*	On	4	2	4	4	NS	4
American Bison *Bison bison*	Off	4	2	4	4	4	4
Big Horn Sheep *Ovis Canadensis*	Off	4	2	4	4	4	4
Black Bear *Ursus americanus*	On	4	1	4	4	4	4
Canadian Lynx *Lynx canadensis*	On	4	1	NS	4	4	4
American Elk *Cervus Canadensis*	Off	4	1	4	4	4	4
Exmoor Pony *Equus ferus caballus*	Off	4	1	4	4	4	4
Fallow Deer *Dama dama*	Off	4	1	4	NS	4	4
Galloway Cow *Bos taurus*	Off	4	1	4	4	4	4
German Shepherd *Canis lupus familiaris*	On	4	1	4	4	4	4
Moose *Alces alces*	Off	4	1	4	4	4	4
Mule Deer *Odocoileus hemionus*	Off	4	1	4	4	4	4
Pronghorn Antelope *Antilocapra americana*	Off	4	1	4	4	4	4
Rabbit *Sylvilagus sp*	On	4	1	4	4	4	4
Red Deer *Cervus elaphus*	Off	4	1	4	4	4	4
Red Fox *Vulpes vulpes*	On	4	1	4	4	4	4
Reindeer/Caribou *Rangifer tarandus*	On	4	1	4	4	4	4
Reindeer/Caribou *Rangifer tarandus*	Off	4	1	4	4	4	4
Roe Deer *Capreolus capreolus*	Off	4	1	3	4	4	4
Soay Sheep *Ovis aries*	On	4	1	4	4	4	4
Soay Sheep *Ovis aries*	Off	4	1	4	4	4	4
Toggenburg Goat *Capra aegagrus hircus*	On	4	1	4	NS	4	4
Toggenburg Goat *Capra aegagrus hircus*	Off	4	2	3	4	4	4
Wild Boar *Sus scrofa*	Off	NS	2	4	NS	NS	NS
Average UV Reaction of a Fresh Cut by Tannage Type		**4.00**	**1.23**	**3.92**	**4.00**	**4.00**	**4.00**
1: **None** 2: **Interior** 3: **Moderate** 4: **Strong**							

Figure 6.3-3. Ultraviolet Light Reaction of a Fresh Cut Edge by Tannage Type. *NS = no sample.

Species	Hair	Alum Taw	Bark Tan	D.S. Brain Tan	W.S. Brain Tan	Urine Tan	Rawhide
Beaver *Castor canadensis*	On		Epidermis fluoresces				
American Bison *Bison bison*	On	Thin interior strip glows yellow-green not white under UV	Very thick interior stripe		Light trans. visible only in darkened conditions		
Big Horn Sheep *Ovis Canadensis*	Off		Hair roots and shafts fluoresce		Grain remnants fluoresce more strongly than surrounding dermis.		
Exmoor Pony *Equus ferus caballus*	Off				Grain remnants fluoresce more strongly than surrounding dermis.		Mane stripe .6 -.8 mm thick
Fallow Deer *Dama dama*	Off	Scars glow more strongly under UV than normal tissue		Grain and membrane remnants fluoresce more strongly than dermis.			
Galloway Cow *Bos taurus*	Off		Lack of UV reaction surprising as compacted fibres can be seen and felt	Light translucence only visible in dark conditions.			
Moose *Alces alces*	Off			Interior stripe fluoresces more strongly that surrounding dermis.			
Rabbit *Sylvilagus sp*	On		Some very minimal light translucence in complete darkness.		Scar tissues fluoresce more strongly than surrounding dermis.		
Red Deer *Cervus elaphus*	Off		Hair roots fluoresce				
Toggenburg Goat *Capra aegagrus hircus*	On					Epidermis fluoresces weakly and flesh side is dull (dirty?)	
Toggenburg Goat *Capra aegagrus hircus*	Off		Very thin interior strip under UV				
Wild Boar *Sus scrofa*	Off		Weak interior UV reaction	Very strong UV reaction			

Figure 6.3-4. Miscellaneous Attributes of Samples by Tannage Type.

6.4 Microscopic Characteristics

Moving away from characteristics which are as immediately noticeable as those identified in the macroscopic section, these microscopic characteristics, though more subtle, also offer clues to the identification of tannage type.

Fibre Size

Though the original fibre size being observed is ultimately a product of what species is being looked it, with a sample collection where the same individual of a species was tanned using six methods, some basic comparisons between tannage types were made possible. As noted in chapter 5, section 5.3, some variance in fibre size appeared to exist between the tannage types. When the literary size designations used to describe fibre size were replaced and represented numerically, this tendency became easier to identify. Though not drastic, the size differences were observable when the averages of each tannage type were compared.

Vegetable tan showed the largest average fibre size on a scale of 0-5, with 'not visible' at the bottom and 'very large' at the top. The oak bark tanned samples averaged 2.62. This was followed by alum taw at 2.36 and WSBT at 2.35. The slightly acid nature of the bark tan bath may play into this difference, with the fibres plumping slightly due to the lower PH level (Sykes, 1991; Reed, 1972). Alum, as mentioned under 'handle', is also mildly acidic, causing the fibres to swell to some degree (Thomson, 2009).

It was a bit unexpected to see the WSBT fall as close to alum taw as the averages show, as the fullness of the fibres differs between the two tannages. However, it was unsurprising to see WSBT show a larger fibre size average than DSBT, which had an average thickness of 2.32. A possible explanation for this occurrence is that, as the fibres of skins softened in a frame dry, they are held under moderate tension, stretching them and inhibiting the contraction that would otherwise occur upon drying out. WSBT does not undergo this stress and, consequently, the fibres contract naturally as they dry.

Species	Hair	Alum Taw	Bark Tan	D.S. Brain Tan	W.S. Brain Tan	Urine Tan	Rawhide	Avg. Fibre Size by Species
American Badger *Taxidea taxus*	On	3	3	3	3	4	3	**3.17**
Beaver *Castor canadensis*	On	3	2	2	3	2	0	**2.00**
American Bison *Bison bison*	On	5	5	5	5	NS	5	**5.00**
American Bison *Bison bison*	Off	5	5	5	5	5	5	**5.00**
Big Horn Sheep *Ovis Canadensis*	Off	3	2	3	3	3	2	**2.67**
Black Bear *Ursus americanus*	On	4	4	3	3	3	3	**3.33**
Canadian Lynx *Lynx canadensis*	On	1	2	NS	1	1	2	**1.40**
American Elk *Cervus Canadensis*	Off	3	3	3	3	3	0	**2.50**
Exmoor Pony *Equus ferus caballus*	Off	1	2	2	1	1	1	**1.33**
Fallow Deer *Dama dama*	Off	2	3	2	NS	2	0	**1.80**
Galloway Cow *Bos taurus*	Off	4	4	4	4	4	4	**4.00**
German Shepherd *Canis lupus familiaris*	On	2	3	3	2	2	0	**2.00**
Moose *Alces alces*	Off	3	3	3	3	3	3	**3.00**
Mule Deer *Odocoileus hemionus*	Off	1	3	1	1	2	1	**1.50**
Pronghorn Antelope *Antilocapra americana*	Off	2	2	1	2	1	0	**1.33**
Rabbit *Sylvilagus sp*	On	1	1	1	1	1	0	**0.83**
Red Deer *Cervus elaphus*	Off	3	3	2	3	3	0	**2.33**
Red Fox *Vulpes vulpes*	On	1	2	1	1	1	0	**1.00**
Reindeer/Caribou *Rangifer tarandus*	On	2	2	2	2	NS	0	**1.60**
Reindeer/Caribou *Rangifer tarandus*	Off	2	2	2	2	2	0	**1.60**
Roe Deer *Capreolus capreolus*	Off	1	1	1	1	1	0	**0.83**
Soay Sheep *Ovis aries*	On	1	1	1	1	1	0	**0.83**
Soay Sheep *Ovis aries*	Off	1	1	1	1	1	0	**0.83**
Toggenburg Goat *Capra aegagrus hircus*	On	2	3	2	NS	1	0	**1.60**
Toggenburg Goat *Capra aegagrus hircus*	Off	3	3	2	3	1	0	**2.00**
Wild Boar *Sus scrofa*	Off		3	3				**3.00**
Average Fibre Size by Tannage Type		**2.36**	**2.62**	**2.32**	**2.35**	**2.09**	**1.16**	
0: **Not Visible** 1: **Very Fine** 2: **Fine** 3: **Medium** 4: **Large** 5: **Very Large**								

Figure 6.4-1. Fibre Size Variance by Tannage Type. *NS = no sample.

Urine tan had an average size of 2.09, making it the tannage type with the smallest fibre size. It is unclear at present why this tannage type would have smaller fibres than the other two fat tannages.

Many of the rawhide samples were cemented, and in this state the fibres were not visible. The average at 1.16 has little, if any, statistical validity as the fibres which were able to be identified were all from large fibred species. The perceived fibre size recorded for each sample, and the average fibre size by species and by tannage type, are presented in Figure. 6.4-1.

Fibre Definition

The ease of identifying the fibre bundles (fibre definition) was recorded using a scale from 'no definition/none' 0, to 'very well defined' 5. There was a general trend for species with a larger fibre size to consistently score higher than those with finer fibres. There was also variation by tannage type when the averages were compared.

The most obvious of these variations was rawhide, of which very few samples had any identifiable fibres at all, and as a group had an average score of 0.44. Urine tan had the next lowest definition score at 3.26. This was unsurprising, as this tannage type was more difficult to soften than the others and, as such, often had poor fibre separation, making the fibre bundles harder to see in the finer fibred samples.

Alum taw and vegetable tan grouped quite closely with scores of 3.4 and 3.46, respectively. Both of these tannage types require less vigorous softening methods than the fat tannages to achieve a similar level of pliability. They are generally denser tannage types, meaning that the fibre bundles are more compact with less space between them, making them slightly harder to identify.

WSBT scored the highest for fibre definition with 3.74, which falls closest to 'well defined'. This tannage type has the most vigorous softening process of the tannage types, meaning there was often space between the fibre bundles, making them easier to identify. However, as mentioned in chapter 5, section 5.1, when very fine fibred species were also finely separated, samples often scored lower for definition, as the fibres became increasingly difficult to see at 40x magnification. DSBT scored below WSBT with a score of 3.48. This is again most likely attributable to the process of frame softening, which tended to produce more fibre adhesion, and an overall tighter fibre structure than that seen in the WSBT samples. The fibre definition recorded for each sample, and the average fibre definition by species and by tannage type, are detailed in Figure. 6.4-2.

Fibre Separation

The amount of separation of the fibre structure was recorded using a scale from 0 – 'no separation/none', to 5 – 'very finely separated'. Fibre separation showed the opposite tendency, by species, to fibre definition, with finer fibred species generally scoring higher (more finely separated) than the larger fibred species. This is explainable in that the species with larger fibres often also had thicker skins, making them more difficult to soften to the same degree as the thinner-skinned species. Skins which are softened to a lesser degree had more fibre adhesions and more compact fibre structures, with less space between the fibres. When the averages for fibre separation between the tannage types were compared, there were some notable differences.

WSBT and DSBT had significantly higher levels of fibre separation than the other tannage types, and, when averaged, scored 3.57 and 3.44 respectively. This characteristic is responsible for brain tan's light, airy feel, and is a product of removing as much ground substance as possible. This is replaced with very light weight oils which do little to fill the interfibrillary spaces, which, in turn, leaves a large amount of space between the fibres (Haines, 1991c).

Alum taw and urine tan both show the next highest amount of fibre separation with a score of 2.96, followed by bark tan at 2.81. As previously noted, alum taw and bark tan are denser tans, with tanning agents of a larger molecular size which do a more complete job of filling the interfibrillary spaces than those used for fat tanning, likely accounting for the lower scores of these tannage types. The lower urine tan samples' average compared to the other fat tans is, again, likely due to the difficulty in softening these samples to a similar level as the other tannage types. This results in the level of fibre adhesion within the fibre structure being much higher, resulting in less interfibrillary space similar to the thicker-skinned species.

Rawhide, as expected, scored by far the lowest at .44, with no fibre separation visible on most samples. The amount of fibre separation recorded for each sample and the average amount of separation by species and by tannage type, are presented in Figure. 6.4-3.

Species	Hair	Alum Taw	Bark Tan	D.S. Brain Tan	W.S. Brain Tan	Urine Tan	Rawhide	Avg. Definition by Species
American Badger *Taxidea taxus*	On	3	3	5	3	3	1	**3.00**
Beaver *Castor canadensis*	On	3	4	3	4	4	0	**3.00**
American Bison *Bison bison*	On	5	4	4	5	NS	2	**4.00**
American Bison *Bison bison*	Off	5	3	5	5	5	1	**4.00**
Big Horn Sheep *Ovis Canadensis*	Off	3	4	4	4	4	1	**3.33**
Black Bear *Ursus americanus*	On	4	3	3	3	4	1	**3.00**
Canadian Lynx *Lynx canadensis*	On	3	3	NS	2	3	1	**2.40**
American Elk *Cervus Canadensis*	Off	4	4	4	5	4	0	**3.50**
Exmoor Pony *Equus ferus caballus*	Off	2	3	4	2	4	1	**2.67**
Fallow Deer *Dama dama*	Off	3	4	4	NS	3	0	**2.80**
Galloway Cow *Bos taurus*	Off	4	5	4	5	3	1	**3.67**
German Shepherd *Canis lupus familiaris*	On	3	4	4	4	3	0	**3.00**
Moose *Alces alces*	Off	5	4	4	4	4	1	**3.67**
Mule Deer *Odocoileus hemionus*	Off	3	4	3	3	3	1	**2.83**
Pronghorn Antelope *Antilocapra americana*	Off	3	4	3	3	3	0	**2.67**
Rabbit *Sylvilagus sp*	On	2	3	3	3	2	0	**2.17**
Red Deer *Cervus elaphus*	Off	4	4	2	4	3	0	**2.83**
Red Fox *Vulpes vulpes*	On	2	3	2	4	2	0	**2.17**
Reindeer/Caribou *Rangifer tarandus*	On	3	3	4	4	NS	0	**2.80**
Reindeer/Caribou *Rangifer tarandus*	Off	3	3	4	4	4	0	**3.00**
Roe Deer *Capreolus capreolus*	Off	4	3	2	3	2	0	**2.33**
Soay Sheep *Ovis aries*	On	3	3	3	4	3	0	**3.00**
Soay Sheep *Ovis aries*	Off	3	3	4	4	3	0	**2.50**
Toggenburg Goat *Capra aegagrus hircus*	On	4	4	3	NS	3	0	**2.80**
Toggenburg Goat *Capra aegagrus hircus*	Off	4	4	3	4	3	0	**3.00**
Wild Boar *Sus scrofa*	Off	NS	1	3	NS	NS	NS	**2.00**
Average Fibre Definition by Tannage Type		**3.46**	**3.48**	**3.74**	**3.26**	**0.44**	**3.46**	
0: **None** 1: **Very Poor** 2: **Poor** 3: **Moderate** 4: **Well** 5: **Very Well**								

Figure 6.4-2. Fibre Definition by Tannage Type. *NS = no sample.

Species	Hair	Alum Taw	Bark Tan	D.S. Brain Tan	W.S. Brain Tan	Urine Tan	Rawhide	Avg. Separation by Species
American Badger *Taxidea taxus*	On	2	2	3	3	2	1	**2.17**
Beaver *Castor canadensis*	On	2	3	4	3	2	0	**2.33**
American Bison *Bison bison*	On	3	3	3	3	NS	2	**2.80**
American Bison *Bison bison*	Off	3	2	3	3	4	1	**2.67**
Big Horn Sheep *Ovis Canadensis*	Off	3	3	3	3	4	1	**2.83**
Black Bear *Ursus americanus*	On	3	3	4	4	3	1	**3.00**
Canadian Lynx *Lynx canadensis*	On	4	3	NS	4	4	1	**3.20**
American Elk *Cervus Canadensis*	Off	4	3	3	3	3	0	**2.67**
Exmoor Pony *Equus ferus caballus*	Off	2	3	2	5	3	1	**2.67**
Fallow Deer *Dama dama*	Off	4	3	4	NS	1	0	**2.40**
Galloway Cow *Bos taurus*	Off	3	3	3	2	3	1	**2.50**
German Shepherd *Canis lupus familiaris*	On	2	3	3	4	3	0	**2.50**
Moose *Alces alces*	Off	4	3	3	4	4	1	**3.17**
Mule Deer *Odocoileus hemionus*	Off	4	3	5	4	2	1	**3.17**
Pronghorn Antelope *Antilocapra americana*	Off	3	4	4	4	4	0	**3.17**
Rabbit *Sylvilagus sp*	On	2	3	4	4	2	0	**2.50**
Red Deer *Cervus elaphus*	Off	3	4	4	3	3	0	**2.83**
Red Fox *Vulpes vulpes*	On	2	2	3	2	2	0	**1.83**
Reindeer/Caribou *Rangifer tarandus*	On	3	2	3	4	NS	0	**2.40**
Reindeer/Caribou *Rangifer tarandus*	Off	4	3	4	4	3	0	**3.00**
Roe Deer *Capreolus capreolus*	Off	3	3	5	5	3	0	**3.17**
Soay Sheep *Ovis aries*	On	2	3	4	4	4	0	**2.80**
Soay Sheep *Ovis aries*	Off	3	3	4	4	3	0	**2.80**
Toggenburg Goat *Capra aegagrus hircus*	On	3	3	3	NS	2	0	**2.20**
Toggenburg Goat *Capra aegagrus hircus*	Off	3	2	3	3	4	0	**2.50**
Wild Boar *Sus scrofa*	Off	NS	1	2	NS	NS	NS	**1.50**
Separation by Tannage Type		**2.96**	**2.81**	**3.44**	**3.57**	**2.96**	**0.44**	

0: **None** 1: **Very Poorly** 2: **Poorly** 3: **Moderately** 4: **Finely** 5: **Very Finely**

Figure 6.4-3. Amount of Fibre Separation by Tannage Type. *NS = no sample.

Fibre Weave

The amount which the fibres interweave with one another was observed for each sample and recorded using a scale ranging from 0 – 'not visible', to 5 – 'very loosely'. There is a strong correlation between the tightness of the fibre weave and species, with the difference between species with the tightest fibre weave (1.50) and with the loosest (3.83), being much more significant than difference seen between most of the tannage types.

Though most are slight, the differences in the average fibre weave between tannage types are visible. It is worth reinforcing here that this criterion is an observation of the fibres visible on the flesh side surface of each sample, and as such is not representative of the fibre weave of the entire dermal thickness. It was recorded however, as a counter part to the cross section observations, which highlight the mid dermal fibres that have not been directly affected by abrasive softening methods.

WSBT and rawhide stand out from the other tannages in the appearance of the fibre weave. Rawhide, unsurprisingly, scores 0 for this criterion, as none of the samples had ample fibre separation to allow the structure of the fibre matrix to be viewed. WSBT in contrast showed the loosest fibre weave of any of the tannage types, with a score of 2.87. This is, again, unsurprising in light of the very aggressive softening this tannage type undergoes.

After rawhide, urine tan had the most tightly interwoven fibre structure, with a score of 2.48. As noted previously, this is likely attributable to the difficulty in attaining good fibre separation during the softening process.

Vegetable tan had an average fibre weave of 2.62. This places the average bark tanned sample between tight and very tight, which is likely the product of the tightening action displayed by the tannins responsible for producing this tannage type.

Both DSBT and alum taw had very close average scores of 2.64 and 2.68 respectively, making the amount of interwovenness displayed by these tannages closer to moderate than tight. As noted previously, the fibres present in DSBT are mechanically restricted to some degree during softening, and this is the likely explanation for the tighter structure seen here in comparison the WSBT samples. The tightness of the fibre structure for alum taw is in keeping with its previously discussed pliability rating. Again, this is most likely caused by the slightly swollen fibres combined with a less aggressive softening process.

The interwovenness of the fibre structure for each sample, and the average tightness of weave by species and by tannage type, are detailed in Figure. 6.4-4.

Species	Hair	Alum Taw	Bark Tan	D.S. Brain Tan	W.S. Brain Tan	Urine Tan	Rawhide	Avg. Weave by Species
American Badger *Taxidea taxus*	On	3	2	2	3	3	0	**2.17**
Beaver *Castor canadensis*	On	3	3	3	3	2	0	**2.33**
American Bison *Bison bison*	On	5	4	4	4	NS	0	**3.40**
American Bison *Bison bison*	Off	4	4	5	5	5	0	**3.83**
Big Horn Sheep *Ovis Canadensis*	Off	3	3	3	2	3	0	**2.33**
Black Bear *Ursus americanus*	On	4	3	4	3	4	0	**3.00**
Canadian Lynx *Lynx canadensis*	On	2	2	NS	2	2	0	**1.60**
American Elk *Cervus Canadensis*	Off	4	4	5	5	4	0	**3.67**
Exmoor Pony *Equus ferus caballus*	Off	1	2	2	2	2	0	**1.50**
Fallow Deer *Dama dama*	Off	2	3	3	NS	2	0	**2.00**
Galloway Cow *Bos taurus*	Off	3	2	3	3	2	0	**2.17**
German Shepherd *Canis lupus familiaris*	On	3	3	3	4	2	0	**2.50**
Moose *Alces alces*	Off	4	4	4	4	4	0	**3.33**
Mule Deer *Odocoileus hemionus*	Off	2	2	2	3	2	0	**1.83**
Pronghorn Antelope *Antilocapra americana*	Off	2	3	1	2	1	0	**1.50**
Rabbit *Sylvilagus sp*	On	2	1	2	3	1	0	**1.50**
Red Deer *Cervus elaphus*	Off	3	4	3	3	4	0	**2.83**
Red Fox *Vulpes vulpes*	On	2	2	2	3	2	0	**1.83**
Reindeer/Caribou *Rangifer tarandus*	On	3	3	2	2	NS	0	**2.00**
Reindeer/Caribou *Rangifer tarandus*	Off	3	3	2	2	3	0	**2.12**
Roe Deer *Capreolus capreolus*	Off	2	2	3	2	1	0	**1.67**
Soay Sheep *Ovis aries*	On	1	2	2	2	2	0	**1.50**
Soay Sheep *Ovis aries*	Off	2	2	2	2	2	0	**1.67**
Toggenburg Goat *Capra aegagrus hircus*	On	2	2	2	NS	2	0	**1.60**
Toggenburg Goat *Capra aegagrus hircus*	Off	2	2	2	2	2	0	**1.67**
Wild Boar *Sus scrofa*	Off	NS	1	0	NS	NS	NS	**0.50**
Average Weave by Tannage Type		**2.68**	**2.62**	**2.64**	**2.87**	**2.48**	**0.00**	
0: **Not Visible** 1: **Very Tight** 2:**Tight** 3: **Moderate** 4: **Loose** 5: **Very Loose**								

Figure 6.4-4. Interwovenness of Fibre Structure by Tannage Type. *NS = no sample.

6.5 Cross Sections

Though the cross sectioned species form a much smaller sample size than those represented by the surface observations section, they serve to focus observations made in the larger collection on the interior portion of the dermis. By looking at the less disturbed mid dermal fibres, characteristics attributable to the different tannage types, can be better identified and explained.

Fibre Size

In contrast to the fibre size findings of the larger sample collection, the cross section observations show fibre size as correlating to species only. This, as mentioned previously, may be a product of the ordinal scale's limitations in reflecting fine detail, such as nuanced fibre size differences. When individual fibres (section 6.5) were measured some variability between tannage types was recorded.

Fibre Fullness

The cross section shape of the fibres was recorded using the designations of 0 – 'not visible', 1 – 'flat', 2 – 'moderately full', and 3 – 'full'. This characteristic has strong ties to tannage type with the three fat tannages: WSBT, DSBT and urine tan showing very flat ribbon-like fibres, alum taw showing moderately full fibres and bark tan showing full, rounded fibres. The only exceptions to these trends were a few WSBT samples, which also showed moderately full fibres. Rawhide's fibres were almost always cemented and not visible. A few rawhide samples from larger fibred species did have a few visible fibres. These were also flat and ribbon-like.

As mentioned previously the plumping of the fibres can be caused by soaking in the alkaline solutions used to dehair the skins. However, this is unlikely to be the case for the sample collection, as the samples were well rinsed, and the PH neutralised before being moved to the tanning solutions. This attribute is especially interesting in a collection like this, where the different tannage types can be directly compared across a single species. Figure. 6.5-2 details the fullness of the fibres seen in each sample and the average fullness of the fibres by species and tannage type.

Compactness

Compactness was measured using a scale from 1 – 'cemented', to 5 – 'loose/airy', the details for which are recorded in Figure. 6.5-3. There was a general trend for the thicker-skinned species to be more compact; however, there was also a distinct correlation between the level of compactness present and the tannage type. The most obvious correlation was, as usual, seen in rawhide with its unanimously cemented fibre structure. This was followed by bark tan with a score of 2.43, making it the most compact of the garment grade tannage types. Alum taw, with a general score of 2.86 was slightly less compact, but still much less airy, than the fat tans. Of the fat tannages, urine tan was the most compact, with a score of 3.29, as expected in light of the fibre weave and separation seen in the surface observations. The two brain tans showed the least compactness seen across the tannage types, with scores of 3.43 for WSBT and 3.86 for DSBT. These scores too are in keeping with the higher levels of fibre separation and more loosely interwoven fibre structures detailed previously. It was surprising, though, to see DSBT score as less compact/more airy than WSBT.

In this case, the disparity between the two brain tans is, most likely, attributable to the larger amount of force able to be applied to the DSBT samples for Bison and Galloway than could be applied by hand softening, as done for WSBT. This is due to the size of the samples, as the small size of the WSBT samples did not give good purchase for hand softening. These very thick-skinned species require a large amount of force to adequately manipulate the fibres during the drying process. Had the WSBT samples been larger in size, it is believed, based on the author's previous experience that they too would be more in line with the compactness levels seen for DSBT, or possibly looser still.

Splitting-Up

The splitting-up of the fibre bundles was recorded with a scale from 0 – 'no splitting up/none', to 5 – 'finely split up'. The amount of fibre splitting-up for each sample, and the average amount of splitting-up by species and by tannage type, are detailed in Figure. 6.5-4. This attribute was less clear cut than compactness but had general tendencies by both species and tannage type, with thicker skinned species typically showing less splitting-up than that seen in the fibres of the more thinly skinned species. This is again likely to reflect a bias, due to the relative softness achieved between these species.

Between the tannage types, rawhide again showed a consistent lack of any visible splitting-up across all samples viewed, while both brain tans showed a moderate amount with a score of 2.14 for both WSBT and DSBT. Alum taw and urine tan fell between 'little' and 'moderate' amounts of splitting-up, with bark tan showing slightly more splitting-up with a score of 2.00. The higher scores for the brain tans are again likely caused by the aggressive softening which breaks the fibre bundles apart more finely than in the other tannage types.

Species	Alum Taw	Bark Tan	Urine Tan	W.S. Brain Tan	D.S. Brain Tan	Rawhide	Avg. Size by Species
American Bison *Bison bison*	5	5	5	5	5	5	**5.00**
Galloway Cow *Bos taurus*	4	4	4	4	4	4	**4.00**
Moose *Alces alces*	3	3	3	3	3	0	**2.50**
Red Deer *Cervus elaphus*	3	3	3	3	3	0	**2.50**
Reindeer/Caribou *Rangifer tarandus*	2	2	2	2	2	0	**2.00**
Soay Sheep *Ovis aries*	2	2	2	2	2	0	**2.00**
Toggenburg Goat *Capra aegagrus hircus*	2	2	2	2	2	0	**1.67**
Average Fibre Size by Tannage Type	**3**	**3**	**3**	**3**	**3**	**1.3**	
0: **Not Visible** 1: **Very Fine** 2: **Fine** 3: **Medium** 4: **Large** 5: **Very Large**							

Figure 6.5-1. Fibre Size by Tannage Type.

Species	Alum Taw	Bark Tan	Urine Tan	W.S. Brain Tan	D.S. Brain Tan	Rawhide	Avg. Fullness by Species
American Bison *Bison bison*	2	3	1	1	1	1	**1.50**
Galloway Cow *Bos taurus*	2	3	1	2	1	1	**1.67**
Moose *Alces alces*	2	3	1	1	1	0	**1.33**
Red Deer *Cervus elaphus*	2	3	1	2	1	0	**1.50**
Reindeer/Caribou *Rangifer tarandus*	2	3	1	1	1	0	**1.60**
Soay Sheep *Ovis aries*	2	3	1	1	1	0	**1.60**
Toggenburg Goat *Capra aegagrus hircus*	2	3	1	1	1	0	**1.33**
Average Fibre Fullness by Tannage Type	**2.00**	**3.00**	**1.00**	**1.29**	**1.00**	**0.29**	
0: **Not Visible** 1: **Flat** 2: **Moderately Full** 3: **Full**							

Figure 6.5-2. Fullness of Fibres by Tannage Type.

Species	Alum Taw	Bark Tan	Urine Tan	W.S. Brain Tan	D.S. Brain Tan	Rawhide	Avg. Compactness by Species
American Bison *Bison bison*	3	2	3	2	4	1	**2.50**
Galloway Cow *Bos taurus*	2	2	2	2	4	1	**2.17**
Moose *Alces alces*	3	3	2	4	3	1	**2.67**
Red Deer *Cervus elaphus*	3	3	4	4	4	1	**3.17**
Reindeer/Caribou *Rangifer tarandus*	3	2	4	4	4	1	**3.40**
Soay Sheep *Ovis aries*	3	3	4	4	4	1	**3.60**
Toggenburg Goat *Capra aegagrus hircus*	3	2	4	4	4	1	**3.00**
Average Compactness by Tannage Type	**2.86**	**2.43**	**3.29**	**3.43**	**3.86**	**1.00**	
1: **Cemented** 2: **Very Compact** 3: **Moderately Compact** 4: **Loose/Airy**							

Figure 6.5-3. Compactness of the Fibre Structure by Tannage Type.

Species	Alum Taw	Bark Tan	Urine Tan	W.S. Brain Tan	D.S. Brain Tan	Rawhide	Avg. Splitting by Species
American Bison *Bison bison*	1	2	1	2	2	0	**1.33**
Galloway Cow *Bos taurus*	1	2	1	2	2	0	**1.33**
Moose *Alces alces*	2	2	1	2	2	0	**1.50**
Red Deer *Cervus elaphus*	2	2	1	2	2	0	**1.50**
Reindeer/Caribou *Rangifer tarandus*	2	2	1	3	2	0	**2.00**
Soay Sheep *Ovis aries*	1	2	2	2	3	0	**2.00**
Toggenburg Goat *Capra aegagrus hircus*	1	2	2	2	2	0	**1.50**
Average Splitting by Tannage Type	**1.43**	**2.00**	**1.29**	**2.14**	**2.14**	**0.00**	
0: **None** 1: **Little** 2: **Moderate** 3: **Finely**							

Figure 6.5-4. Splitting-Up of the Fibre Bundles by Tannage Type.

Angle of Weave

The angle of weave was recorded using the designations, 1 – 'horizontal, 2 – 'low', 3 – 'medium', and 4 – 'high'. The score assigned to each sample, and the average scores by species and by tannage type, are detailed in Figure. 6.5-5. The angle of weave shows some variation by species, but slightly more variation by tannage type. The denser tannage types (alum taw and vegetable tan) had generally higher angles of weave, with an average score of 3.14 for each, than the fat tans (urine tan, WSBT, and DSBT). Both WSBT and DSBT scored an average of 2.71, making the angle of weave slightly closer to medium than that of urine tan, which had an average score of 2.57. Rawhide, as expected, was horizontal for most samples, and had an average score of 1.14. Possibly, because of the filling nature of tannins and alum, the fibre structure retains more of its natural weave pattern, whereas the skins tanned with fats have less well supported fibre structures, leading to slightly lower angles of weave in the final product. This seems more prevalent in species with thicker skins, which do not attain the same amount of loft during softening as do the thinner skins.

Appearance of the Fibre Network

The appearance of the fibres was recorded using the designations 0 – 'not visible', 1 – 'small curves', 2 – 'small curves with crinkle', 3 – 'crinkled', 4 – 'large curves' and 5 – 'straight'. There were three occurrences of fibres with a crinkled appearance; two in the same species (moose), and two in the same tannage type (alum). It is unknown whether or not this aspect of appearance is more influenced by species or tannage type. While there is a trend toward a looser fibre structure characterised by large curves or straight fibre appearance, for thinner skinned species, there is also a strong correlation between the fibre network appearance and tannage type.

Rawhide, with the lowest score of .29, has little to no visible fibre structure. The vegetable tanned samples had an average of 1.43, and most were labelled as 'small curves'. Alum taw's average of 2.29 puts it in the slightly looser range. If the crinkle designation is put aside, however, and only curves considered, then the alum tawed Red Deer and Moose are both designated as 1's, making the average 1.86. This is looser than bark tan, but still maintaining more curve structure than that seen in the fat tans. Urine tan and WSBT had very close averages at 3.83 and 3.86 respectively. This was followed DSBT with the highest average at 4.71.

There was a distinct tendency for the light, airy, open fibre structure of the fat tans to be characterised by a fibre network with a straight appearance. Alum and bark tan both maintain the interweaving of the fibre structure in a more natural state, characterised by small to large curves and occasionally accompanied by crinkled fibres. The fibre network appearance for each sample, and the average appearance by species and by tannage type, are detailed in Figure. 6.5-6.

Species	Alum Taw	Bark Tan	Urine Tan	W.S. Brain Tan	D.S. Brain Tan	Rawhide	Avg. Weave by Species
American Bison *Bison bison*	3	4	2	2	3	2	**2.50**
Galloway Cow *Bos taurus*	4	4	2	2	2	1	**2.50**
Moose *Alces alces*	3	3	2	3	2	1	**2.33**
Red Deer *Cervus elaphus*	3	2	3	3	3	1	**2.50**
Reindeer/Caribou *Rangifer tarandus*	3	3	3	3	3	1	**2.80**
Soay Sheep *Ovis aries*	2	3	3	3	3	1	**2.80**
Toggenburg Goat *Capra aegagrus hircus*	4	3	3	3	3	1	**2.83**
Average Weave by Tannage Type	**3.14**	**3.14**	**2.57**	**2.71**	**2.71**	**1.14**	
1: **Horizontal** 2: **Low** 3: **Medium** 4: **High**							

Figure 6.5-5. Angle of Weave Observed by Tannage Type.

Species	Alum Taw	Bark Tan	Urine Tan	W.S. Brain Tan	D.S. Brain Tan	Rawhide	Avg. Appearance by Species
American Bison *Bison bison*	1	1	Disordered	1	4	1	**1.60**
Galloway Cow *Bos taurus*	1	1	1	1	5	1	**1.67**
Moose *Alces alces*	3	1	2	5	4	0	**2.50**
Red Deer *Cervus elaphus*	2	1	5	5	5	0	**3.00**
Reindeer/Caribou *Rangifer tarandus*	4	1	5	5	5	0	**4.00**
Soay Sheep *Ovis aries*	1	4	5	5	5	0	**4.00**
Toggenburg Goat *Capra aegagrus hircus*	4	1	5	5	5	0	**3.33**
Average Fibre Appearance by Tannage Type	**2.29**	**1.43**	**3.83**	**3.86**	**4.71**	**0.29**	
0: **Not Visible** 1: **Small Curves** 2: **Small Curves with Crinkle** 3: **Crinkle** 4: **Large Curves** 5: **Straight**							

Figure 6.5-6. Fibre Network Appearance by Tannage Type.

6.6 Individual Fibre Analysis by Tannage Type

Individual fibres were examined to assess whether or not differences noted in the cross sections would be echoed in the individual fibres. The fibres were assessed by measuring their size and observing their fullness, outline, surface texture, lustre, and the level of translucence and splitting-up. These criteria are detailed for each sample and organised by tannage type in Figure. 6.6-1. Pictures showing fibres from each tannage type for comparison are presented in Figure. 6.6-2 and Figure. 6.6-3. Figure. 6.6-2 shows large fibres from Bison at 40x original magnification and Figure. 6.6-3 shows much finer fibres from Toggenburg Goat at 80x original magnification.

Fibre Size

To supplement and cross check the ordinal scale used to determine fibre size, the individual fibre from both reference species were measured digitally using a newly available Axio Vision SE64 camera system. The measurements supported the variability of fibre size between the tannage types recorded for the complete sample set in section 6.4. Bark tan and alum taw were both thicker than the three fat tanned skins. Bark tan was thicker than alum taw for the Bison fibres, but the opposite was true for the Toggenburg fibres. In both species DSBT and urine tan had thinner fibres than WSBT. The DSBT Bison fibres were thinner than those from the urine tanned Bison sample. Of the Toggenburg fibres, DSBT and urine tan were found to be close in size.

Fibre Fullness

As in the cross sections the 'fullness' was recorded for the individual fibres, using the descriptive terms 'flat', 'moderately full' and 'full'. As with the cross section findings, the individual fibres showed that the shape of the fibres differed between the tannage types. The oak bark tanned samples showed fuller rounder fibres than the flat, ribbon-like fibres seen in DSBT, WSBT and urine tan. Alum tawed fibres fell between these two extremes and were termed moderately full.

Fibre Outline

The outline of the individual fibres were compared between the different tannage types, and were recorded using the designations, 'crinkled', 'undulations', and 'straight'. The three fat tans had much straighter outlines than the outlines of the bark tanned samples. The fibres from the alum tawed samples had a crinkled appearance, which supports the tannage type as causing this effect, and brings into question it being a species-based characteristic. What in the alum taw process causes this crinkling effect is at present unknown.

Surface Texture

The surface texture of the individual fibres was observed and described as either 'textured' or 'smooth'. Both vegetable tan and alum taw had more textured surfaces than those of the three fat tans, which were very smooth.

Lustre

The way light reflected from the surface of each fibre was noted, and was described as 'dull', 'sheen' or 'shiny and reflective'. Again, the fat tans were very distinctive in having a glassy shine to the surface of the fibres – so much so that the glare made photographing them difficult. Those from DSBT and WSBT were slightly easier in this respect than the urine tanned fibres, as the colouration imparted by the smoke reduced the glare somewhat. The bark tan and alum taw were much less reflective than the fat tans, though the Toggenburg fibres reflected more brightly than the duller fibres of the Bison sample.

Translucence

While the translucence of the individual fibres between the tannage types was not as clear cut as the distinction seen when shining light through the complete samples or the cross sections, it was still discernible. There was no ambiguity in the translucence of the fat tans or alum taw fibres, which allowed light to pass through seemingly unhindered. However, the finer bark tanned fibres from the Toggenburg allowed some light to pass through, as opposed to the cross section and whole sample from the same species, which blocked all visible light. The thicker bark tanned fibres from the Bison were not translucent, in keeping with the cross section and whole sample findings from this species.

Splitting up

The amount of splitting up seen in the individual fibres was generally greater in fibres from the fat tanned samples than those from the denser tans. The bark tanned Bison fibres were more finely split-up than the alum tawed fibres, but Toggenburg fibres from both tannages showed little splitting-up.

Comparative photographs of the fibres from the different tannage types detailing the criteria outlined above can be seen for a large fibred species (Bison) in Figure. 6.6-2, and for a finer fibred species (Toggenburg Goat) in Figure. 6.6-3.

Species	Alum Taw	Bark Tan	Urine Tan	W.S. Brain Tan	D.S. Brain Tan
Fibre Size in μm					
American Bison *Bison bison*	116.02	149.12	116.42	122.82	86.44
Toggenburg Goat *Capra aegagrus hircus*	62.71	49.56	38.09	46.41	39.55
Fibre Fullness					
American Bison *Bison bison*	Moderate	Full	Flat	Flat	Flat
Toggenburg Goat *Capra aegagrus hircus*	Moderate	Full	Flat	Flat	Flat
Fibre Outline					
American Bison *Bison bison*	Crinkle	Undulations	Straight	Straight	Straight
Toggenburg Goat *Capra aegagrus hircus*	Crinkle	Undulations	Straight	Straight	Straight
Fibre Surface Texture					
American Bison *Bison bison*	Textured	Textured	Smooth	Smooth	Smooth
Toggenburg Goat *Capra aegagrus hircus*	Textured	Textured	Smooth	Smooth	Smooth
Fibre Lustre					
American Bison *Bison bison*	Dull Lustre	Dull Lustre	Shiny Reflective	Shiny Reflective	Shiny Reflective
Toggenburg Goat *Capra aegagrus hircus*	Sheen	Sheen	Shiny Reflective	Shiny Reflective	Shiny Reflective
Fibre Translucence					
American Bison *Bison bison*	Yes	No	Yes	Yes	Yes
Toggenburg Goat *Capra aegagrus hircus*	Yes	Slightly	Yes	Yes	Yes
Splitting-Up of Fibres					
American Bison *Bison bison*	Little	Moderate	Moderate	Moderate	Fine
Toggenburg Goat *Capra aegagrus hircus*	Little	Little	Fine	Fine	Moderate

Figure 6.6-1. Individual Fibre Analysis Table.

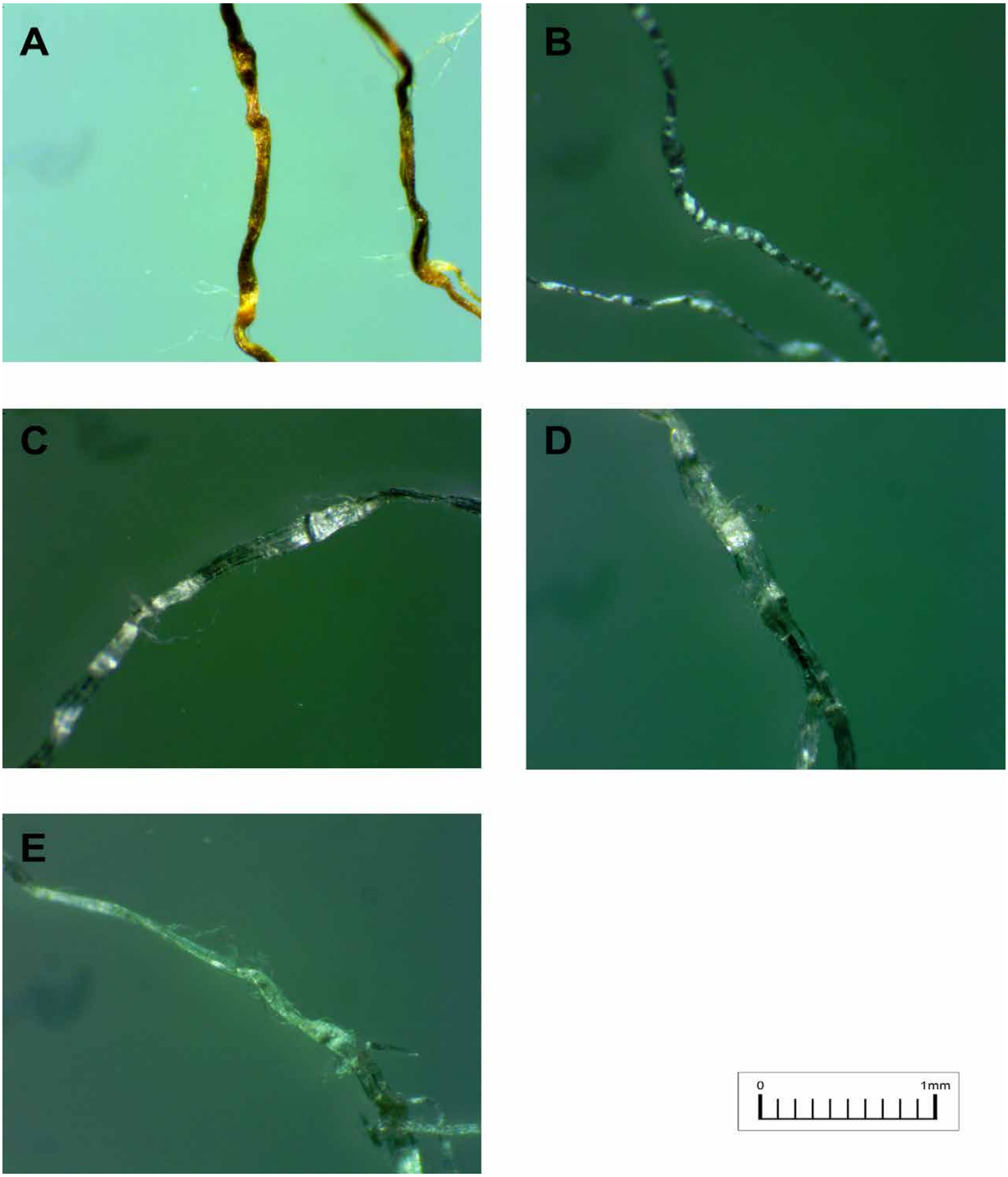


Figure 6.6-2. Individual Fibres- Comparison by Tannage Type: **A**- Bark tan, **B**- Alum taw, **C**-DSBT, **D**- WSBT, **E**- Urine tan. Species: Bison, Original magnification 40x, Scale = 1 mm.

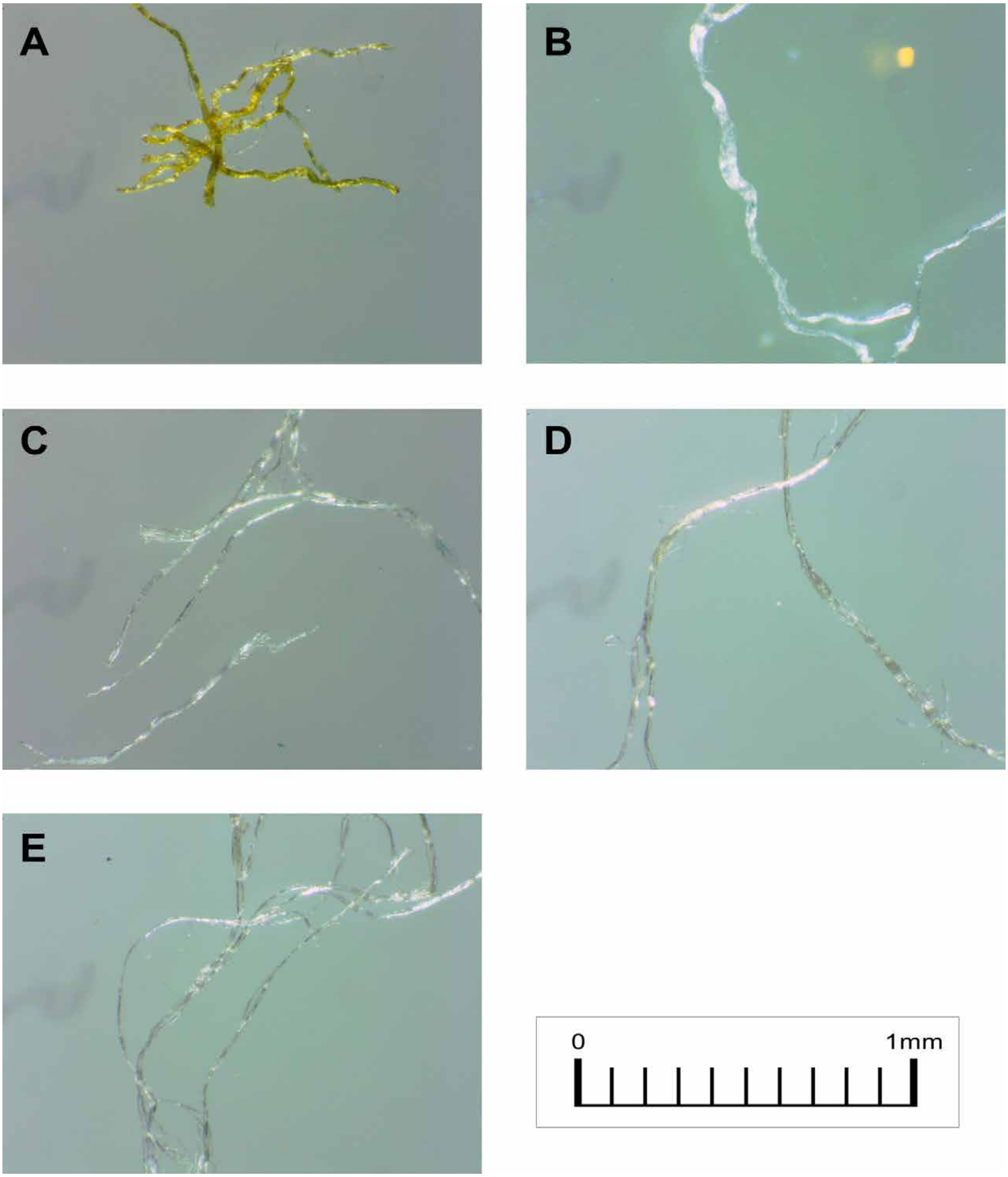


Figure 6.6-3. Individual Fibres- Comparison by Tannage Type: **A**- Bark tan, **B**- Alum taw, **C**-DSBT, **D**- WSBT, **E**- Urine tan. Species: Toggenburg Goat, Original magnification 80x, Scale = 1 mm.

Chapter 7

Identification of In-Life Use Traces. Analysis of Modern Reference Collection of Traditionally Tanned Clothing

7.1 Introduction to In-Life Use Traces

In addition to the characteristics defined in the preceding two chapters, a set of characteristics formed during the use life of processed skin objects was assessed. These were first noticed when examining modern items made from traditional tannages with known object biographies. These characteristics appear to be heavily influenced by tannage type and were also found in many of the archaeological items later analysed during fieldwork. These in-life use traces are some of the most significant and exciting findings of this research.

As detailed in chapter 2, the various tannage types behave in different ways when subjected to stress. The most common stress type endured by processed skin items is stretch. Whether it is lace for lashing or a seam holding together two pieces of skin, the amount of stretch, and the severity of the deformation it causes, create identifiable and predictable patterns depending on the tannage type. Because these patterns are produced during the object's life, the interpretation of these patterns is less subject to distortion due to the preservation environment. As is the case with stretch, some of these traces become more prominent the longer the item is in use. Others – notably traces of manufacturing sequence, such as, intentional removal of the grain surface – may become obscured through wear.

The following section outlines the traces seen in the author's modern reference collection of clothing and footwear, made from traditional tannage types and later seen in museum artefacts. As in the previous sections, each description is accompanied by photographs to visually illustrate the characteristics in question. These are found at the end of the section.

7.2 Manufacturing Sequence

The presence or absence of the grain layer on a skin object gives clues to its later treatment with tanning agents. The removal of the grain layer, with its very fine and tight fibre structure, facilitates the penetration of oils applied to lubricate the dermal fibres during fat tanning. Its removal also allows the skin a much greater ability to stretch, as the difference between the tightness of the dermal fibres found in the grain and mid-dermis/corium has been removed. This is not to say that fat tanning cannot be done with the grain layer in place, but that when the product desired is a very soft skin, many traditional tanners, both modern and ethnographic, appreciate that its removal makes the softening process significantly less challenging (Mason, 1891; Rahme, 2006; Richards, 1997; Young *et al.*, 1991; Klokkernes and Kunstakademi, 2007).

There is, conversely, very little reason to remove the grain layer if a vegetable tannage is to be used. The grain layer is one of the attributes which makes vegetable tanning desirable as it can be treated to repel water much more effectively than a suede surface. Again, this is not to say that vegetable tanned flesh splits are an impossibility, as they were certainly produced historically (Reed, 1972; Covington, 2011). However, considering the tool technologies available prehistorically, an even split (where two usable halves of the thickness of the skin are produced) seems unlikely. It also seems unlikely that the removal and consequent destruction of the grain before tanning with bark, other than for possible aesthetic reasons, would have been a process which was routinely undertaken.

There is no reason whatsoever to remove the grain layer for making rawhide. The hair is often slipped or shaved off, but no examples of a rawhide where the grain layer has been intentionally removed have been encountered by the author to date.

Following on from this, the identification of the presence or absence of the grain layer is one clue to any later tannage treatment the processed skin item may have undergone. Caution must be exercised, however, and account taken of both wear and over-tannage or colouration when making any assumptions based on the presence or lack thereof of the grain layer. The impact of wear is the easier of the two variables to establish. An item may appear to have been de-grained, when in fact the grain has simply worn away through use. A close inspection of any seams or other such protected areas, which could shelter a more original surface, can often yield an answer in the form of remnant hairs, hair roots, and grain pattern, or, in much worn cases, just a few follicle remnants here and there. These remnant follicles are occasionally seen in poorly or expediently de-grained skin items as well, so should not be completely relied upon. Conversely, wear as seen in Figure. 7.2-1, in the armpit area of a modern combination tan (wet scrape brain tan over-tanned (soaked) with Black Walnut hull solution) vest top, has produced a surface that resembles worn-down grain. Upon closer inspection, however, there are no hair roots or follicles, and, when a fingernail is run lightly over the surface, the fibres re-separate into a suede surface.

The second variable, over-tanning or colouring, is trickier to identify and separate from the tannage type itself. Surface treatments like colouring often show up quite obviously in cross section. As cutting a cross section from a museum object is seldom an option, natural breaks in the skin surface can sometimes serve a similar purpose, allowing the interior dermal fibres to be observed. Differences in colour, lustre, and fullness can give clues to any surface treatments applied, and possibly inform the analysis of how they were applied. Colours applied as a thick paste to create patterns, contrasting colouration of the flesh to grain sides, or bands of colour, seldom penetrate to the interior of the skins thickness. Where the colour has faded completely, but a surface treatment is suspected, such as a skin which has fat tanned characteristics but does not transmit light, looking at the interior using UV light will cause any collagen which has not come into contact with tannins to glow (Reed, 1972: 253-254). This can also be used to identify similar collagen stripes through the interior of what otherwise appears and behaves as a vegetable tanned skin, possibly indicating a vegetable tan which has been 'rubbed on', or simply one not left in the tanning bath long enough to tan through. Raw stripes can be produced unintentionally or intentionally (as detailed in chapter 4) as a way of controlling the characteristics of the finished product, so caution should be exercised in interpreting the reason for raw stripes.

Over-tannage or combination tanning is very difficult to prove. There is ample ethnographic evidence for fat tanned skins over-tanned with vegetable solutions, resulting in combination tans which push and often exceed the limits of this method of microscopic analysis. The surface of these tans often appears within the spectrum for fat tans, and often the cross sections will appear as airy, empty fibre structures. However, the skin behaves in a way more akin to vegetable tan, with holes that do not overstretch and squarer edges.

While the presence or absence of grain has direct relevance to tannage type identification, the next two remnants of the manufacturing process give more circumstantial evidence for tool types, and suspension methods used during the reductive processes prior to tanning. Even though this falls outside the goals set for this research is it worth noting. A few artefacts had large holes that didn't match up well with stitch holes, or even lace holes for closures. They did, however, match well to holes from being laced into a frame or pegged out on the ground for scraping or softening. The holes were large, severely stretched and all showed linear stretch patterns around the outside half of their circumference. Figure. 7.2-2 shows one of these holes from the experimental collection and an archaeological example.

A second set of manufacturing traces seen were tool marks, usually encountered on the flesh side. This most often showed up as a series of shallow parallel lines on the surface, presumably caused by using a tool with a serrated edge. This is unsurprising in that most retouched stone scrapers are mildly serrated, and even bone fleshing tools often have serrated edges (Mason, 1891). The term serrated needs clarification here, as it is used in many different ways by different researchers. When talking about scrapers for hide working serration refers to a tool edge which has not only had a primary set of flakes removed, but one that also has had the sharp points created by this process knocked off as well, to form a mildly serrated edge which will not damage the skin with any overly sharp points. This process has been documented ethnographically in southern Ethiopia for hide tanners of the Konso and Gamo peoples who still use stone scrapers for skin processing (Weedman, 2005: 175-195).

These tool marks have been noted by other researchers as well and Torunn Klokkernes has consolidated a list of museum items from Sami and Evenk cultures in her

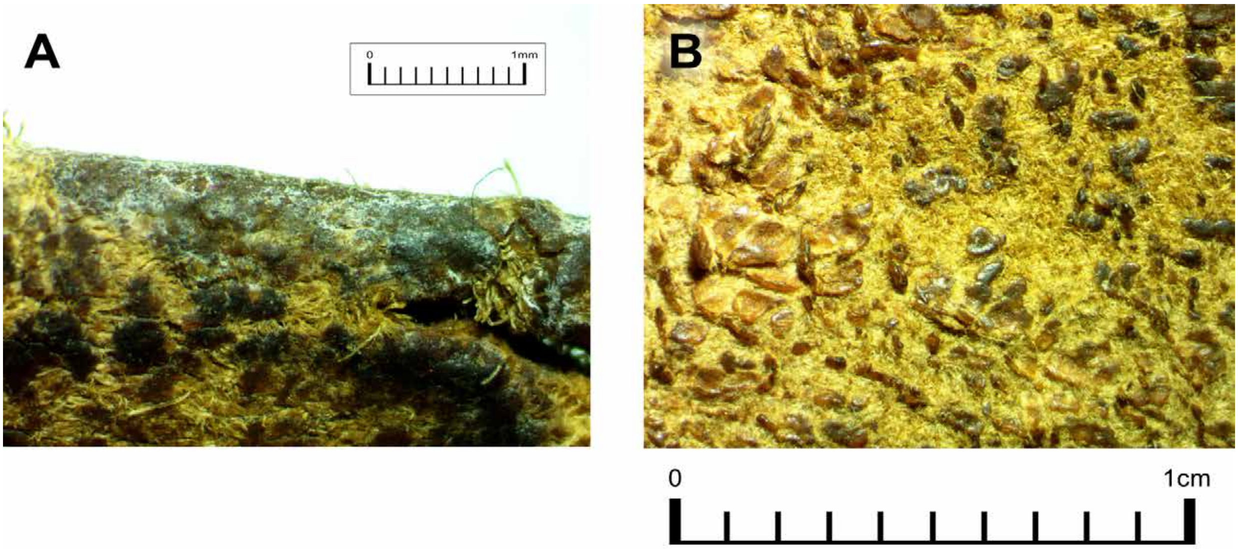


Figure 7.2-1a and 1b. **A**-Faux grain effect with salt staining 30x, **B**- Fibres which look like grain (faux grain effect) due to body oils and hardening 10x.

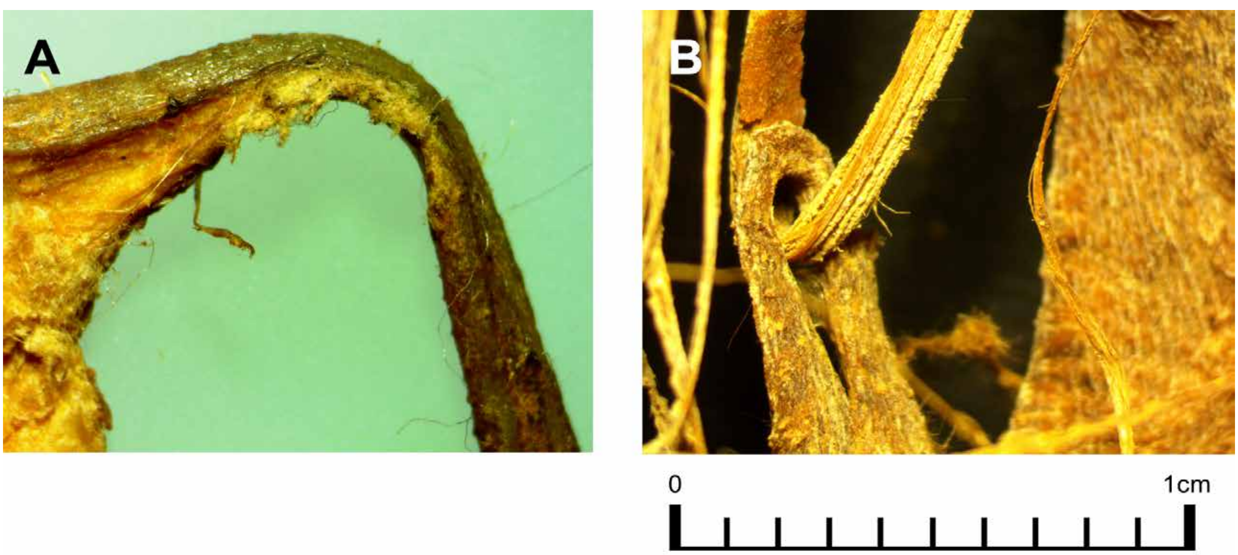


Figure 7.2-2a and 2b. Overstretched holes from lacing skin into a frame: **A**- Example from sample collection, **B**- Archaeological example from dry preservation site. Original magnification 10x.

PhD thesis showing these tool marks on historic items (Klokkernes and Kunstakademi, 2007: 91). Tool marks which form while de-graining dried, framed skins with stone tools, have been personally observed by the author, over the course of her tanning experience, which are similar to those seen on historical and archaeological items. They form in a less prominent way when the skin is de-fleshed in a frame while still wet using stone tools (Figure. 7.2-3). No marks which survive into the finished product, have been noted when using serrated bone tools for de-fleshing in a frame, or when using unserrated (smooth) bone tools for de-fleshing and de-graining over a beam.

7.3 Edge Morphology

When the edges of processed skin clothing in the modern reference collection were studied, an appreciable difference in edge morphology was observed. This was especially prominent on thongs or lace cut from the different tannage types. The terms thong and lace are used interchangeably to describe long, thin strips of skin. The

Figure 7.2-3. Tool Marks on Rawhide- Dried rawhide laced into a frame, showing tool marks (seen parallel lines) from using a stone scraper to de-flesh the skin.

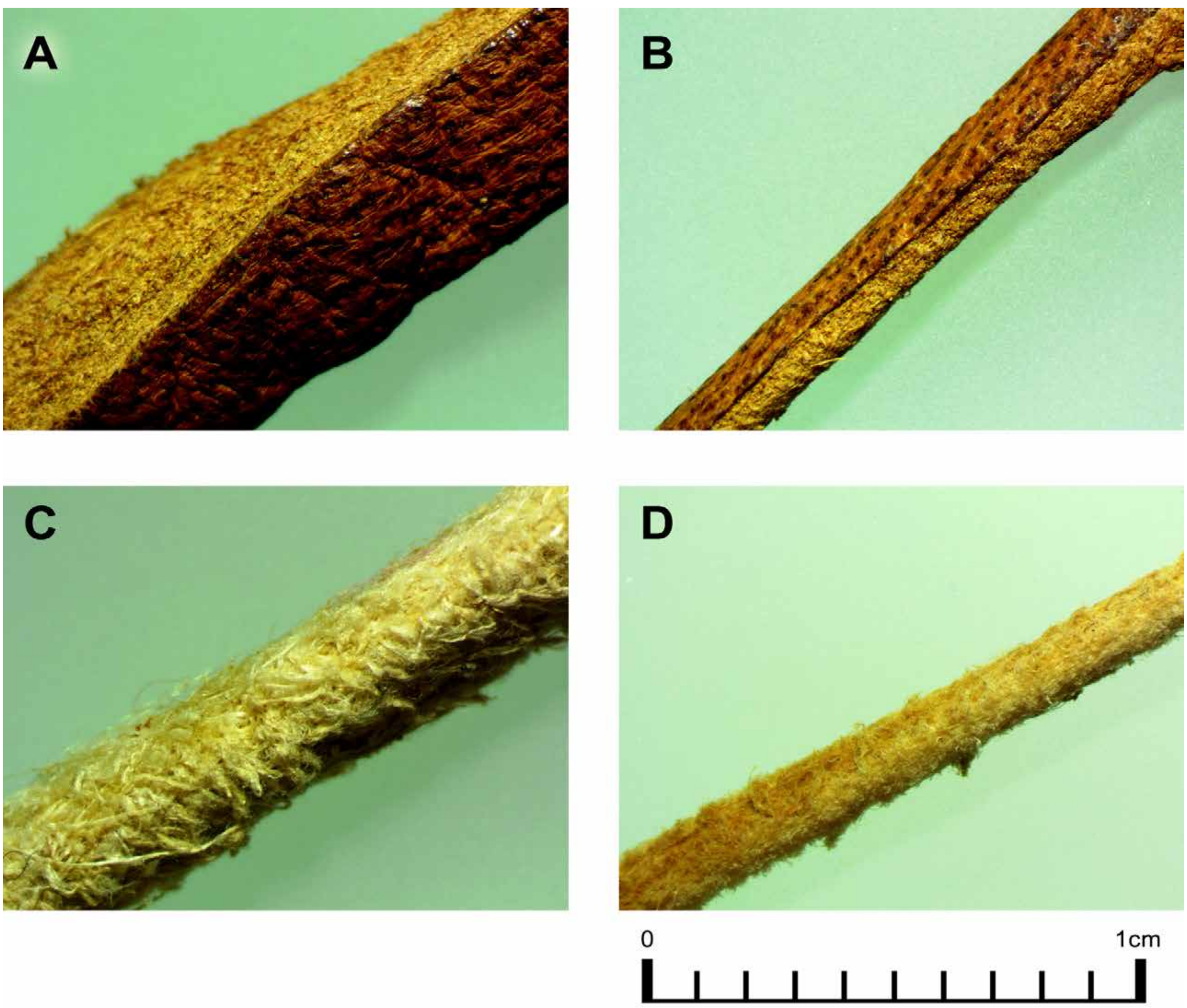


Figure 7.3-1. Edge Appearance- **A**: Square edges on vegetable tan (thick skin), **B**: Square edges on vegetable tan (thin skin), **C**: Rounded edges on brain tan (thick skin), **D**: Rounded edges on brain tan (thin skin). Thick skin = Elk (*Cervus canadensis*), Thin = Mule Deer (*Odocoileus hemionus*), Original magnification 10x.

denser tannages (vegetable tan, alum taw and rawhide) had much squarer edges than those present in tannages with an airy, open fibre structure (wet and dry scrape brain tan, and urine tan). This difference was still apparent after significant use of the clothing and thongs. There was also the possibility that the edge morphology might be a relic of using metal tools to cut the leather, which in turn gave it a more squared edge. To address this, small pieces of lace were cut using an un-retouched flint flake. They were then wetted and stretched by running them through the palm of the author's hand until completely dry, in an effort to simulate some degree of use abrasion and stretch. The disparity in edge appearance remained the same.

The edges observed on vegetable tanned items were very square and held this shape more definitively than the very rounded edges of brain tanned items (Figure. 7.3-1). Rawhide edges were very square if cut when the skin was mostly to completely dry, but had curled over or rounded edges after use, or if cut when it was wet or damp. Using stone tools to cut shapes from fully dried raw hide is difficult, to put it mildly, and rawhide is much more efficiently cut when it is about three quarters dry for shapes, and when very damp for lace. Rawhide lace shrinks significantly as it dries and is often used wet as a lashing material, to take advantage of the extra tightness afforded by this characteristic. Lace that has dried in place has its own set of characteristics, including a glassy appearance, pronounced linear stress lines, and if bent in the dry state it develops light coloured horizontal marks which are caused by the fibre structure in these places separating slightly (Figure. 7.3-2). Urine tan has edges more akin to those seen on the brain tanned items, though with a bit more angle definition on the grain side as the grain, is still intact. Alum taw was the only other tannage to maintain a more rectangular edge and it is still less defined than that of the vegetable tanned items viewed (Figure. 7.3-3).

The grain surface on the vegetable tan lace shows a distinctive surface appearance made up of fine grooves and ridges, produced by linear stretch. It shares this appearance to a lesser degree with the other grain on tannages. The surface of the grain-off brain tans showed no linear grooving. This is unsurprising as there is no differential stretch between the grain and mid-dermal layers, caused by the differing tightness of the two sets of fibre structures. The flesh side can sometimes be distinguished as a darker stripe down the middle of the thong in brain tan. The reason for this colour difference is unknown, but may be due to the finer, fluffier fibres on the flesh side simply holding more dirt or debris than the denser fibred grain side. There was also some grain cracking present on the alum taw when subjected to this level of stretching. The grain on the urine tan examples did not develop surface cracks. The grain side surface features of vegetable tan, alum taw, and urine tan thongs are summarised in Figure. 7.3-4.

In addition to the edge morphology of thong made from processed skin being an indicator of tannage type, the thinness can also narrow down the possible tannages used to produce the skin from which the lace was made. Very thin and even lace, with a high tensile strength, can be produced from the grain-off fat tans. Especially fine lace can be made from species with a tight fibre weave such as pronghorn and goat. This is done by cutting the lace as evenly as possible, then wetting the lace and stretching it around an object to dry. Lace made in this manner is thin enough to string fine beads with and strong enough to withstand use in the structural seams of clothing. This very thin lace, in the author's experience, is unable to be replicated using other tannage types. Lace produced using a grain-on fat tan is often less even due to the grain cracking when the lace is stretched. This leaves an uneven surface that not only creates weak spots along the lace but catches on the seam holes as it is pulled through. Lace made to a similar size from vegetable tanned skin does not have the required tensile strength and breaks with much less force than that which can be applied to lace made from fat tans.

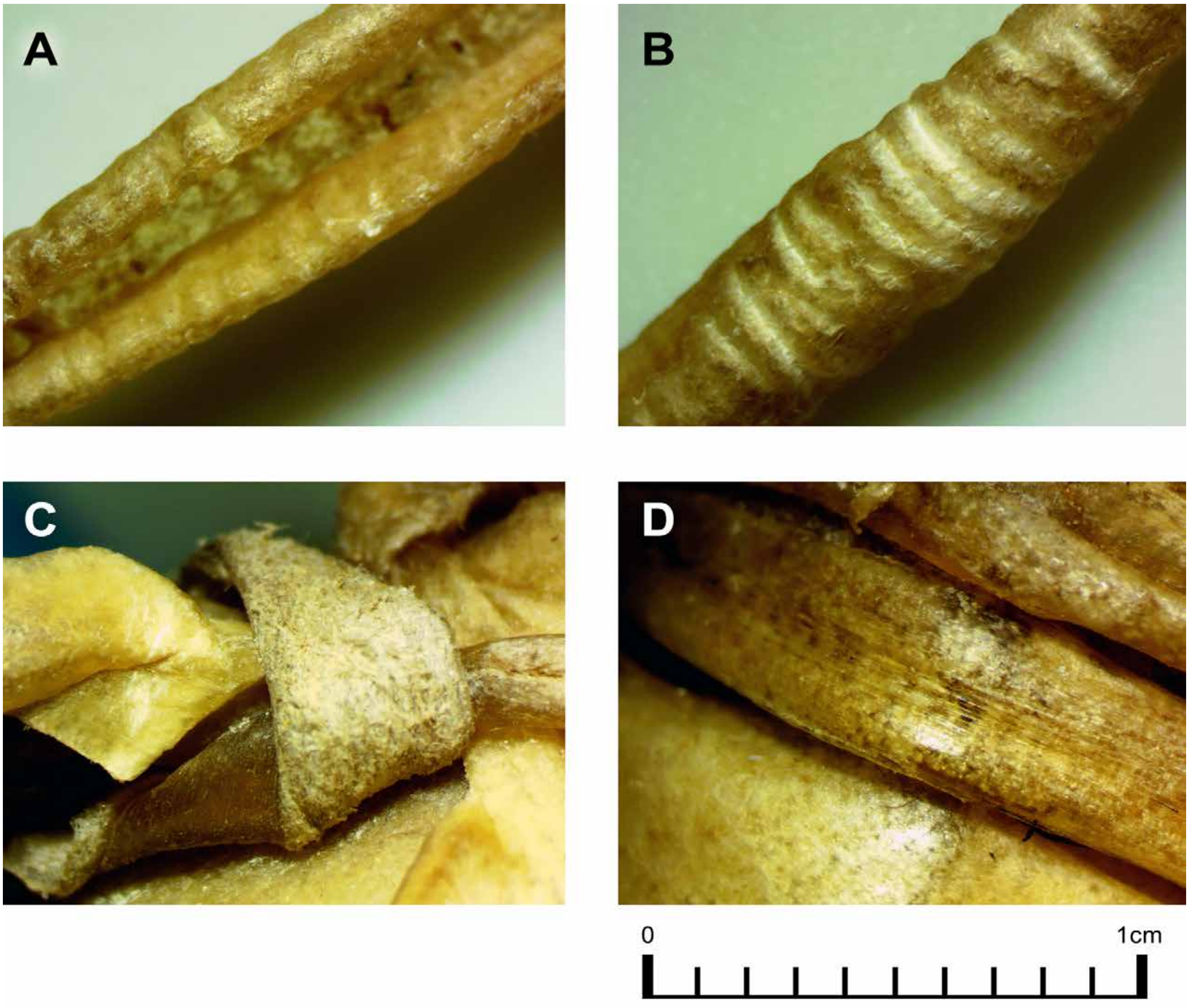


Figure 7.3-2. Edge Appearance and Surface Traits of Rawhide Thong- A: curled edges (seen in thin skins), B: Horizontal marks produced from bending, C: Rounded edges (seen on thicker skins), D: Linear stress marks from drying in position. Original magnification 10x.

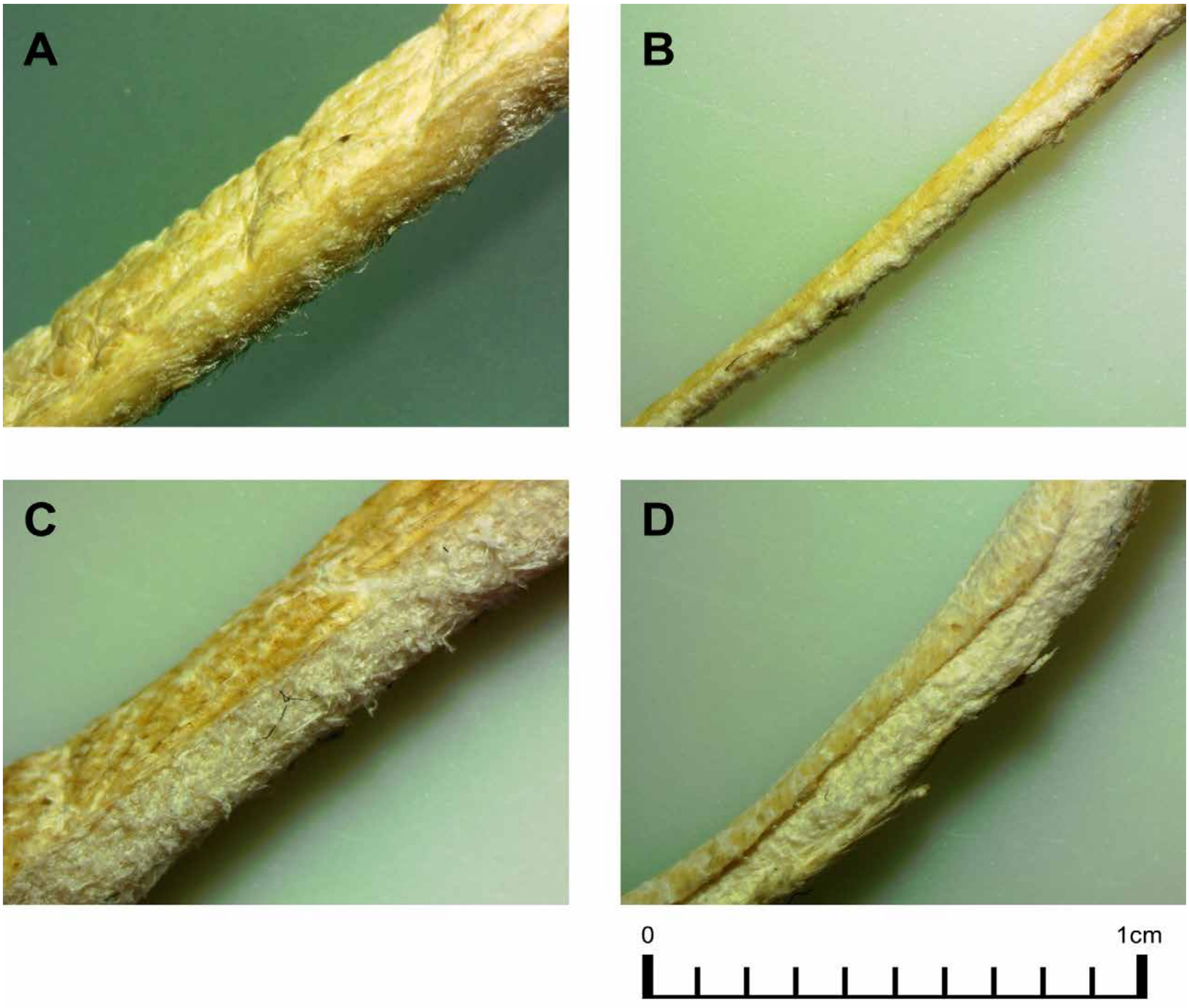


Figure 7.3-3. Edge Appearance- Top: Semi-square edges on alum taw (**A**: thick skin, **B**: thin skin), Bottom: Rounded edges with some definition at the conjunction of the grain and mid-dermis on urine tan (**C**: thick skin, **D**: thin skin), (Thick skin = Elk (*Cervus canadensis*), Thin = Mule Deer (*Odocoileus hemionus*)), Original magnification 10x.

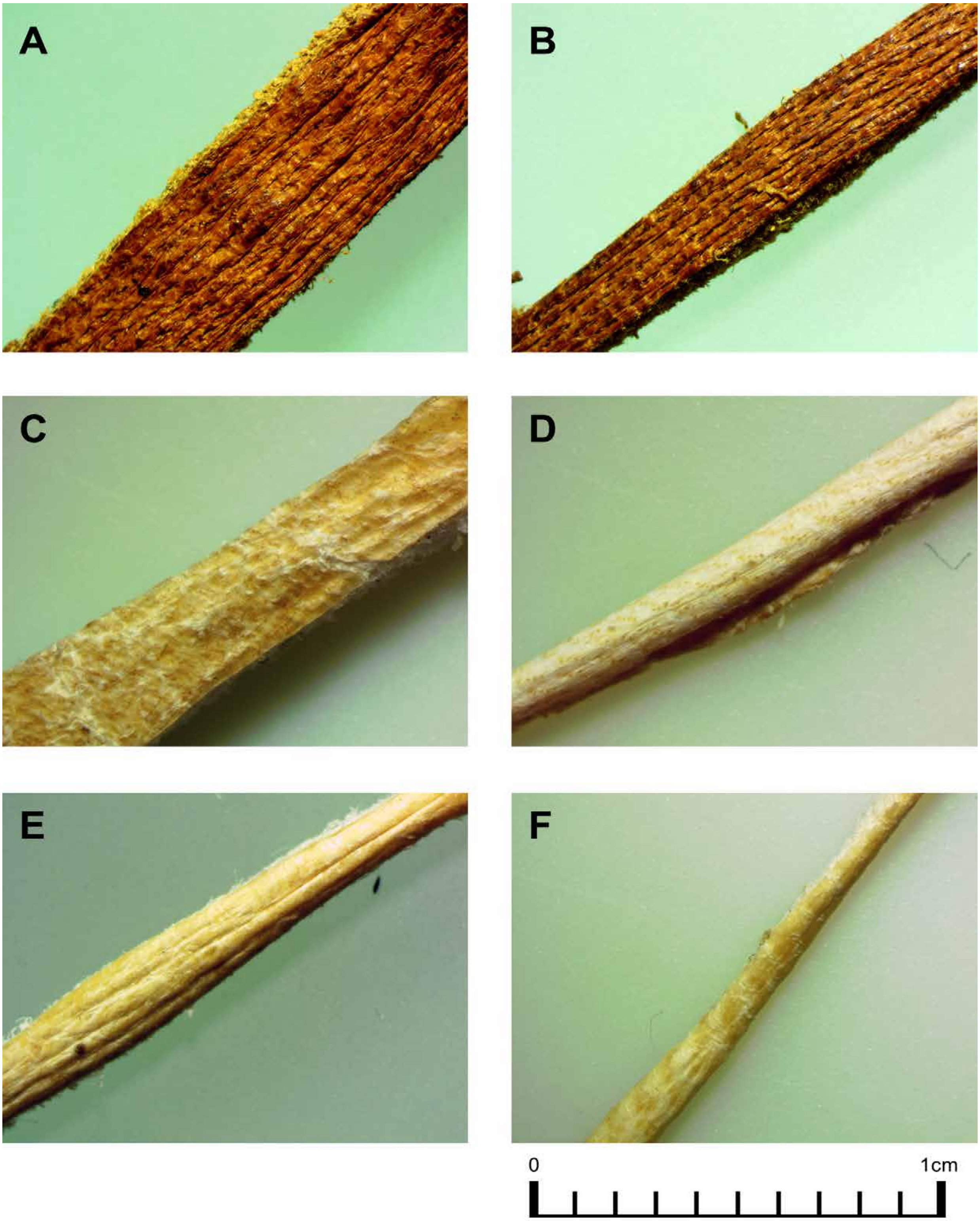


Figure 7.3-4. Thong Surface Traits: Top- Linear stress lines in thick (**A**) and thin (**B**) bark tan, **C**- Cracked grain seen in thick alum taw, **D**- linear stress lines in thin alum taw, Bottom: Linear stress lines in thick (**E**) and thin (**F**) urine tan. Thick skin = Elk (*Cervus canadensis*), Thin = Mule Deer (*Odocoileus hemionus*), Original magnification 10x.

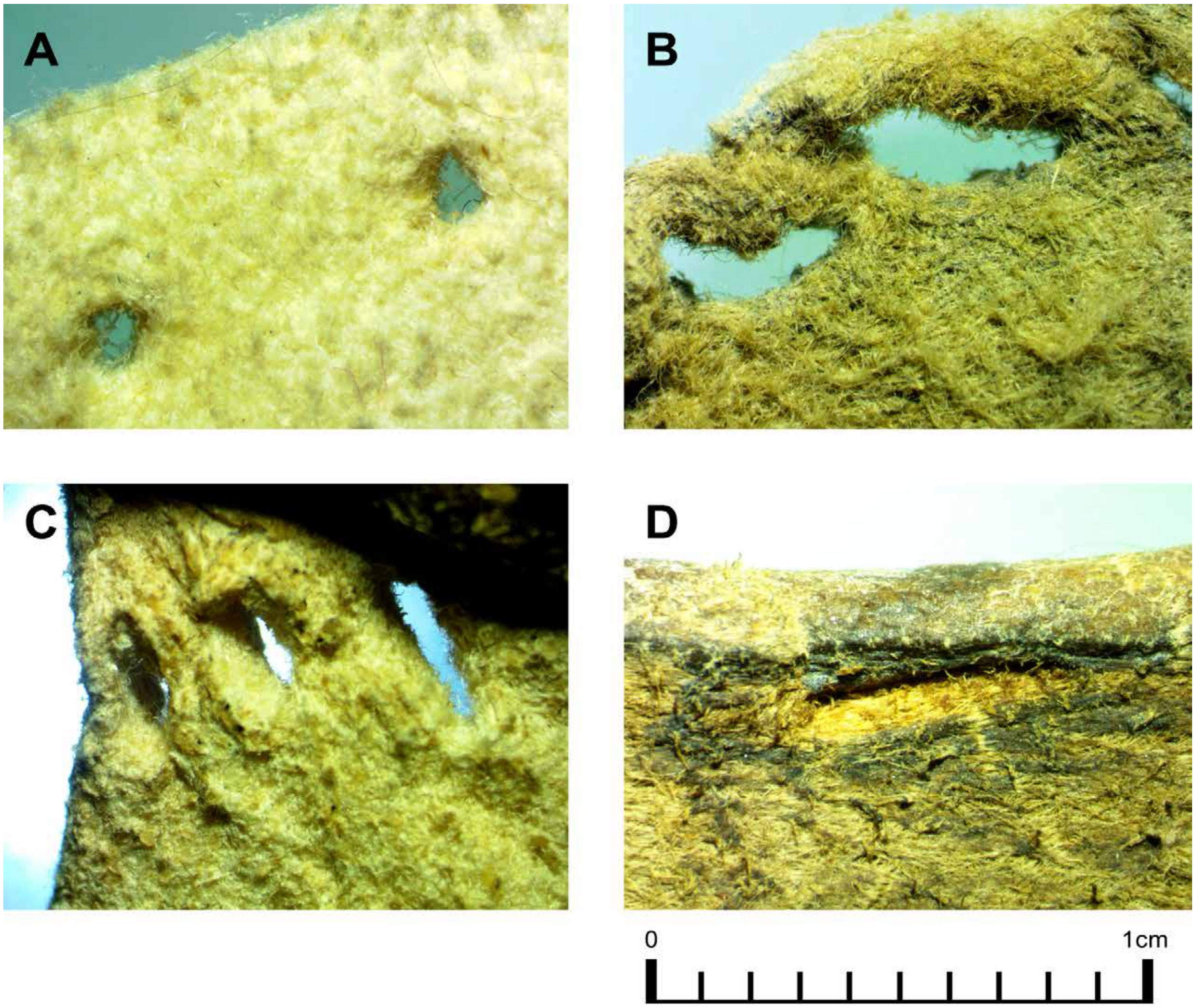


Figure 7.4-1. Hole Behaviour in Fat Tans- **A**: Very lightly stressed hole, **B**: Severe diagonal stress, **C**: Severe stress 90 degrees to the seam, **D**: Moderate stress parallel to the seam. Original magnification 10x.

7.4 Hole Appearance

The differing densities of the various tannage types and the reactions to stress caused by stretching, also cause visible differences in the morphology of holes. Holes which are produced by pushing an awl through the skin's thickness show a rounded shape in brain tanned items, before any stress from wear is introduced. An awl is used because it does less damage to the skin than a sharp perforating tool. An awl pushes the fibres apart as opposed to cutting or breaking them. The more fibres broken when producing the hole, the more the hole will stretch. When stressed, these holes pull out of shape to varying degrees, depending on how much pulling they undergo and how often they are worn wet or damp (Figure. 7.4-1). Being worn wet or damp will cause seam holes in brain tan to stretch drastically. This deformation causes large oval and sometimes irregular shaped holes which seldom have points anywhere around the circumference. Even holes which are cut as a slit into brain tan (meaning that they start with two points at either end) will often stretch into a round or oval shape when stressed over time.

This tendency to overstretch is also seen at its most extreme in rawhide. If worn when wet or allowed to dry stretched too tightly over a mould, holes in rawhide will overstretch to an amazing extent. If made when wet, the holes will form to the seam, preserving the stitch pattern admirably. There will also be linear stretch marks pulling toward the direction of the stress (to the middle of a seam, in the direction a lace is pulled, etc.) similar to those seen in the holes used to lace raw skins into a frame (Figure. 7.4-2).

In vegetable tan, awl holes instead have pointed ends where the grain splits when the awl is pushed through,

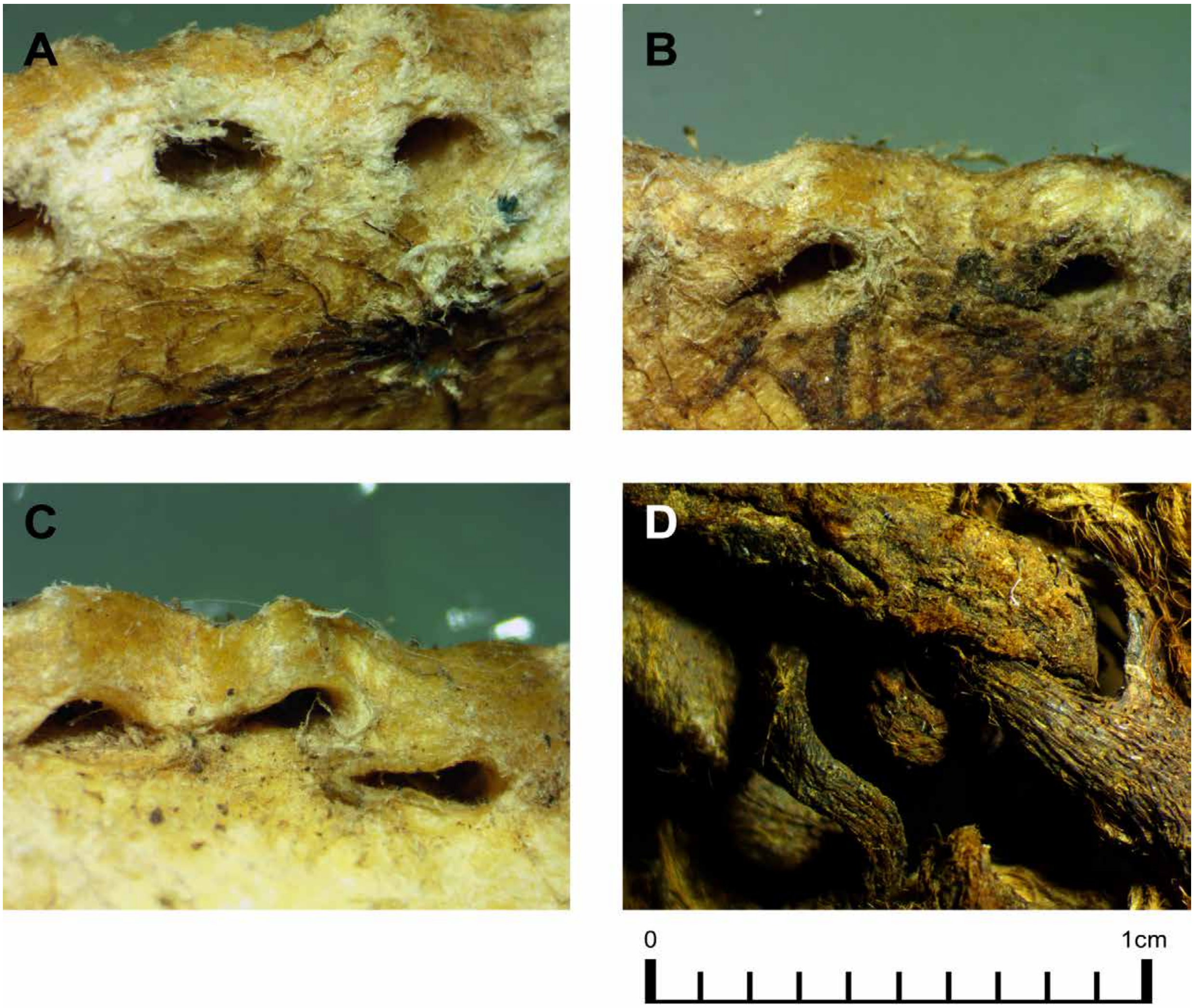


Figure 7.4-2. Hole Behaviour in Rawhide- **A**: Hole with little stress, **B**: Hole with moderate stress, **C**: High stress (thick skin), **D**: High stress (thin skin). Original magnification 10x.

creating a star like appearance, especially apparent in thicker skins. The tightening action of the tannins employed in the vegetable tanning process means that the dermal fibres have a lessened ability to stretch. This is compounded by the intact grain layer, which further inhibits overstretching. Due to this, vegetable tanned items seldom show the large oval holes seen in the less dense tannages. They instead have more of a tendency to remain round, with less directional indication, and frequently maintain points somewhere in their circumference (Figure. 7.4-3). No highly stressed items made from vegetable tan were owned by the author, and instead a few museum objects, which were of obviously vegetable tanned material (historically collected ethnographic material), are used to illustrate hole morphology.

The main variable for hole and, to a lesser extent, edge morphology seems to be the thickness of the skin used in the object, with thick skin stretching less (when subjected to a similar amount of stress) than thin skin of the same tannage type. In light of this, thickness needs to be taken into account when analysing a processed skin object, as a thin skin processed using a dense tannage type, such as vegetable tan, may stretch a similar amount to a thicker skin of a less dense tannage type such as brain tan. Upon making note of the skin thickness of the object in question, it should then be compared to known examples of a similar thickness. When compared this way the differences in hole shape are still observable.

7.5 Tooling

A characteristic unique to vegetable tanned leather is its ability to be tooled (Reed, 1972: 79). Tooling consists of depressing the grain side with reasonable force, using tools

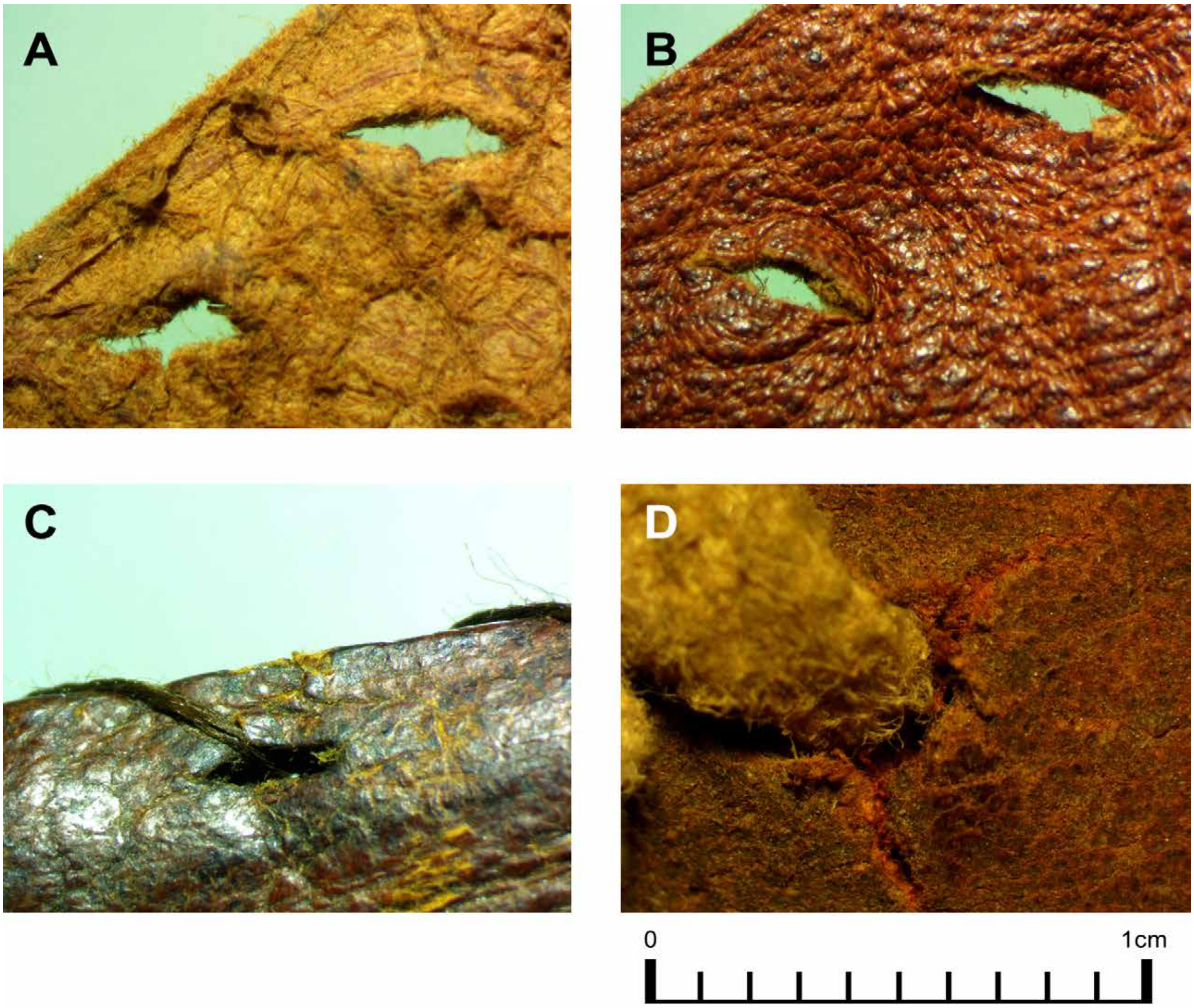


Figure 7.4-3. Hole Behaviour in Bark Tan- Top: Lightly stressed holes (**A**) Flesh side, (**B**) Grain side, **C**: Moderately stressed hole in thin bark tan, **D**: Star shaped pattern from awl being pushed through thick bark tan. Original magnification 10x.

in a variety of shapes, to produce a permanently recessed pattern (Groneman, 1974). The aesthetic potential of this characteristic is unlikely to have been overlooked by ancient craftspeople. This characteristic does survive interment and is observable on later Roman age leather items. Whether or not tooling would as a visually appreciable surface treatment on earlier skin items which may have had shorter times in the tan bath or which may have been produced by rub-on solutions, remains to be proven. If, however it does survive, as suggested for a small leather artefact in the National Museum of Copenhagen's collection, it would strongly support the use of vegetable tan during this artefact's time period. This ability to take and hold an impression is also of use diagnostically, for discerning the stitch type used based on the impressed pattern of an object's seams.

7.6 Wear

It is suspected, based on the author's use of various tannage types for soles on footwear that, the tannage's response and breakdown due to abrasion would also be of diagnostic importance. However, a collection of footwear with the needed variety of tannage types and a sufficient amount of wear time is not yet complete. Other types of wear such as the degradation of the underarm areas of the garment would likely differ according to each tannage type's ability to cope with acidic fluids such as sweat. Burnishing, as a response to surface wear (as opposed to intentional burnishing, a polishing technique for grain on leathers) may also have diagnostic potential between the different grain on tannage types.

7.7 Conclusion

While chapter 7 has introduced a number of in-life use traces, more research remains to be done, to truly flesh out this promising area within tannage identification. Greater interaction between processed skin researchers and the re-enactment and primitive technology groups has the potential to add depth to comparative collections used for this purpose and will be expanded upon in the discussion chapter 10.

Following on from presenting the traits associated with the use of articles made from differing tannage types in this chapter, chapter 8 brings together these individual elements to form a more cohesive system of identification for processed skin objects.

Chapter 8

Tying it All Together: Summaries of Discriminating Traits by Tannage Type and Preservation Context

8.1 Introduction

Nearly all of the characteristics discussed in chapters 5, 6 and 7 have relevance to tannage type. However, most can also be influenced by at least one other variable, and some characteristics provide more clear-cut indications of tannage type than others. There is a need, therefore, to identify multiple characteristics before attempting to classify the tannage type of the item being assessed. In light of this, chapter 8 provides discussion by tannage type of the key characteristics which pertain to each of the six tannages. These primary indicators of tannage type are supported by characteristics which, while not exclusive to one tannage type, can exclude others, lending support to key characteristics observed, or helping to narrow down the options if the more primary characteristics are absent.

These summaries of discriminating characteristics and tendencies for each of the six tannages covered by this research are followed by a discussion of the strengths and limitations of tannage identification based on these features, and how they might pertain to archaeological sample analysis. Exposure, differing preservation contexts and conservation treatments are discussed and the impact of each on the identifying characteristics considered.

8.2 Summaries of Defining Characteristics and Tendencies by Tannage Type

Rawhide

Rawhide is perhaps the easiest of the tannage types to identify or rule out. It is defined by a cemented structure resulting in a fibre network, with little to no separation or definition. This cemented structure makes the surface of rawhide smooth to the touch, though with use the surface can become more textured. The high adhesion rate between the fibres also results in a product with no stretch, and a very stiff handle. The minimal processing that rawhide receives means that the grain layer is very likely to have been left intact, also adding to its smooth surface texture. This minimal processing is also responsible for the very dense nature of rawhide, as the non-collagenous interfibrillary proteins are, for the most part, left in situ. There can be some removal of the ground substance if the rawhide has been dehaired using an alkaline solution.

Light travels easily through rawhide, and it reacts strongly to UV light. The density of the fibre structure means that surface treatments do not often penetrate into the internal dermal structure. This, in turn, means that a reaction to UV light will most likely occur on cross sections, even if there has been a surface treatment applied. When viewed in cross section, minimally-used rawhide will appear nearly smooth. If heavily used during life, some of its fibre structure may become visible, but will for the most part separate into laminated layers of fibre, giving the impression of horizontal lines in cross section.

Defining Characteristics		Tendencies
	Macroscopic	
Colour	Translucent to cream	
Surface Text- Grain	Smooth	
Surface Text- Flesh		Smooth or rough and scratchy
Thickness		Thinnest end of average for the species
Pliability	Very Stiff	
Static Stretch	None	
Fibre Rolls		None
Membrane Remnants		Varies
Light Translucence	Yes	
UV Reactivity- Surface	Strong	
UV Reactivity- Cut edge	Strong	
	Microscopic	
Fibre Size		Low end of species average
Fibre Definition	None	
Fibre Separation	Little to None	
Fibre Weave	Not Visible	
Fibre Fullness	Not Visible or Flat	
Cross Section		
Compactness	Very Compact	
Splitting-Up		Little to None
Angle of Weave	Horizontal to Low	
Fibre Network Appearance	Not Visible	
	Individual Fibre Appearance	
Fibre Outline		Straight when visible
Fibre Surface Texture		Smooth
Fibre Lustre		Shiny and Reflective
Fibre Translucence	Yes	
	In-Life Use Traces	
Edge Appearance	Square when freshly cut, Rounded or Curled Over after use	
Hole Morphology	Oval, Severely Stretched, Linear Stress Lines	

Figure 8.2-1. Rawhide- Defining Characteristics and Tendencies.

If individual fibres can be observed, they will have a flat ribbon-like appearance and, if reasonably clean, a shiny, reflective surface.

Rawhide items which have been shaped and used during their life often display distinct linear stress lines from stretch. These are especially apparent on lashing. Holes which were made when the skin was damp and allowed to dry, or used in repeated wet dry cycles, will show a large amount of over-stretching. The edges of seams will have formed to the stitch pattern. The skin around the holes often shows distinct stretch lines, similar to those seen in thong used for lashing.

Rawhide items may have curled edges on thong, or rounded edges. They may have a smaller fibre size than other skin items of similar thickness found on the same site, and they may have a large amount of remnant membrane on the flesh side surface. The defining characteristics and tendencies for rawhide are presented in tabular form in Figure. 8.2-1.

Fat Tannages

The three fat tannage types analysed (wet scrape and dry scrape brain tan, and urine tan) for this research have very similar defining characteristics. In light of this, they are best discussed as a group. Tendencies which separate them from one another are described after the group characteristics.

The grain side surface texture in the fat tans split into two sets: the grain-on urine tan and the two types of grain-off brain tans. DSBT (dry scrape brain tan) and WSBT (wet scrape brain tan), with the grain removed, have surfaces which are fuzzy to some degree. If this type of surface is found and is not a product of the grain wearing off, bark tan, rawhide and (possibly) alum taw can be ruled out with a fair degree of certainty. These tannage types simply do not require this step be carried out, and removing the grain is a labour intensive step, making it unlikely to have been done if not needed in order to produce a soft end product. The opposite is not true, however, and the fat tans cannot be ruled out if the grain is found to be intact. Fat tans can be produced with a full thickness skin – it is simply more work, and the final product is seldom as soft as it would have been had the grain been removed. In addition to making softening more difficult, the grain surface on fat tanned skins often cracks, which inhibits the application of fat/oil or waxes to improve water resistance, makes surface decoration difficult, and is generally aesthetically unappealing. This effect is caused by the oxidation of the emulsified oils introduced into the skin. This process produces aldehydes which react with small amounts of keratin remaining in the grain layer and produce a tendency for the grain to crack (Haines, 1991c: 25). With this information in mind, if the object being observed has had the grain removed, a fat tannage should be suspected.

A defining characteristic of the fat tannages was the lofty, empty fibre structure with a high degree of fibre separation and, often, definition. This structure, when seen in cross section, had a loose/airy level of compactness, with a tendency to have a straight fibre network appearance, a medium angle of weave, and a high degree of splitting-up of the fibre bundles. As a result of the looseness of the fibre structure, the fat tannages displayed a high degree of pliability and stretch, especially in the thinner-skinned species. They often had fibre rolls on the flesh side.

When the individual fibres were viewed, they were flat, ribbon-like, translucent, and had a shiny, reflective lustre. They had a tendency toward straight outlines and a smooth surface texture.

All fat tanned samples showed marked light translucence and fluoresced strongly under UV light. Due to its very soft handle and open fibre structure, surface treatments applied to fat tans have a greater degree of penetration than seen in rawhide, or vegetable tanned samples. If surface treatments containing tannins have been applied to the skin, they may impact the UV reaction through the full dermal thickness.

Behavioural characteristics seen in well-used items made from fat tanned skins included holes with rounded interior contours and a large amount of stretch. The edges of clothing and lacing were rounded. Very thin, even lengths of thong could be produced to use as stitching material.

Dry Scrape Brain Tan

The ways in which DSBT differed from WSBT were subtle. DSBT showed a tendency to have thinner fibres and a more compact fibre structure in cross section than that seen in WSBT of the same species. The grain side surface texture was often slightly less fuzzy than WSBT, and tool marks were more likely to be seen. The defining characteristics and tendencies for DSBT can be viewed in Figure. 8.2-2.

Defining Characteristics		Tendencies
	Macroscopic	
Colour		Cream to Golden Brown
Surface Text- Grain	Various levels of fuzzy	
Surface Text- Flesh		Various levels of fuzzy
Thickness		Middle range of species average
Pliability	Soft to Pliable	
Static Stretch	Stretchy	
Fibre Rolls		Variable
Membrane Remnants		Variable
Light Translucence	Yes	
UV Reactivity- Surface	Moderate	
UV Reactivity- Cut edge	Strong	
	Microscopic	
Fibre Size		Middle to low end of species average
Fibre Definition		Moderately to Well Defined
Fibre Separation		Moderately to Finely Separated
Fibre Weave		Tight to Moderate
Fibre Fullness	Flat and Ribbon-like	
Cross Section		
Compactness	Loose and Airy	
Splitting-Up		Moderate to Fine
Angle of Weave		Low to Medium
Fibre Network Appearance	Straight	
	Individual Fibre Appearance	
Fibre Outline		Straight to Large Curves
Fibre Surface Texture	Smooth	
Fibre Lustre	Shiny and Reflective	
Fibre Translucence	Yes	
	In-Life Use Traces	
Edge Appearance	Rounded	
Hole Morphology	Oval to very over stretched, No Linear stretch lines	

Figure 8.2-2. Dry Scrape Brain Tan- Defining Characteristics and Tendencies.

Defining Characteristics		**Tendencies**
	Macroscopic	
Colour		Cream to Golden Brown
Surface Text- Grain	Various levels of fuzzy	
Surface Text- Flesh		Various levels of fuzzy
Thickness		Middle range of species average
Pliability	Very soft	
Static Stretch	Very stretchy	
Fibre Rolls		Variable
Membrane Remnants		Variable
Light Translucence	Yes	
UV Reactivity- Surface	Moderate	
UV Reactivity- Cut edge	Strong	
	Microscopic	
Fibre Size		Middle range of species average
Fibre Definition		Moderately to Well Defined
Fibre Separation		Moderately to Finely Separated
Fibre Weave		Moderate to Loose
Fibre Fullness	Flat and Ribbon-like	
Cross Section		
Compactness	Moderate to Loose and Airy	
Splitting-Up		Moderate to Fine
Angle of Weave		Low to Medium
Fibre Network Appearance	Straight	
	Individual Fibre Appearance	
Fibre Outline		Straight to Large Curves
Fibre Surface Texture	Smooth	
Fibre Lustre	Shiny and Reflective	
Fibre Translucence	Yes	
	In-Life Use Traces	
Edge Appearance	Rounded	
Hole Morphology	Oval to very over stretched, no Linear stretch lines	

Figure 8.2-3. Wet Scrape Brain Tan- Defining Characteristics and Tendencies.

Defining Characteristics		Tendencies
	Macroscopic	
Colour		Cream to Yellow
Surface Text- Grain		Flat, shiny grain, with low topography
Surface Text- Flesh		Various levels of fuzzy
Thickness		Lower range of Species Average
Pliability	Soft to Pliable	
Static Stretch	Stretchy	
Fibre Rolls		Variable
Membrane Remnants		Variable
Light Translucence	Yes	
UV Reactivity- Surface	Strong	
UV Reactivity- Cut edge	Strong	
	Microscopic	
Fibre Size		Low end of species average
Fibre Definition		Moderate to Low Definition
Fibre Separation		Poorly to Moderately Separated
Fibre Weave		Tight to Moderate
Fibre Fullness	Flat and Ribbon-like	
Cross Section		
Compactness	Moderately Compact to Loose and Airy	
Splitting-Up		Little to Moderate
Angle of Weave		Low to Medium
Fibre Network Appearance	Straight	
	Individual Fibre Appearance	
Fibre Outline		Straight to Large Curves
Fibre Surface Texture	Smooth	
Fibre Lustre	Shiny and Reflective	
Fibre Translucence	Yes	
	In-Life Use Traces	
Edge Appearance	Rounded, but with some definition at the epidermal junction	Some linear stretch lines on thong
Hole Morphology	No information	

Figure 8.2-4. Urine Tan- Defining Characteristics and Tendencies.

Wet Scrape Brain Tan

WSBT had slightly more fibre separation and significantly more stretch and pliability than DSBT. It had a tendency toward a higher degree of fibre definition and a looser fibre weave. The defining characteristics and tendencies for WSBT can be viewed in Figure. 8.2-3.

Urine Tan

Unlike the other fat tans, the urine tan samples had the grain layer left intact. In addition to this difference, the neatsfoot oil used as a lubricant was applied during the softening process as a surface treatment, instead of the samples being immersed in an emulsion, as was done with the WSBT and DSBT samples. Notable differences from the other fat tans are likely a result of the oil not

Defining Characteristics		Tendencies
	Macroscopic	
Colour	Brown, various shades	
Surface Text- Grain	Full, Plump, large amount of topography	
Surface Text- Flesh		Various levels of Fuzzy
Thickness		Thickest end of average for species
Pliability		Lower end of species average
Static Stretch		Lower end of species average
Fibre Rolls		Not many
Membrane Remnants		Few
Light Translucence	None	
UV Reactivity- Surface	None	
UV Reactivity- Cut edge	None, sometimes interior stripe	
	Microscopic	
Fibre Size		Upper end of species average
Fibre Definition		Moderate to Well Defined
Fibre Separation		Poor to Moderate Separation
Fibre Weave		Tight to Moderate
Fibre Fullness	Full and Rounded	
Cross Section		
Compactness	Very Compact	
Splitting-Up		Little to Moderate
Angle of Weave		Moderate to High
Fibre Network Appearance		Small to Large Curves
	Individual Fibre Appearance	
Fibre Outline	Gentle Undulations	
Fibre Surface Texture		Textured
Fibre Lustre	Dull	
Fibre Translucence	None	
	In-Life Use Traces	
Edge Appearance	Distinctly Square	
Hole Morphology	Points around the circumference, little stretch	

Figure 8.2-5. Bark Tan- Defining Characteristics and Tendencies.

being delivered into the mid-dermal area of the skin as effectively as is accomplished with the emulsion method, as well as neatsfoot oil not autoxidising to the same degree as self emulsifying oils such as those contained in more common dressing solutions such as brains and egg yolks.

The urine tanned samples were thinner/less lofty than the other fat tans and had less fibre separation. This lack of fibre separation resulted in samples which tended to have lower levels of pliability and less stretch. When seen in cross section, urine tanned samples tended to have a lower angle of weave, and less splitting up of the fibres than that seen in DSBT and WSBT. In comparison to the other grain-on tannage types, the grain layer of the urine tanned samples was flat, with less topography and a shinier surface. However, the grain layer did not crack. As cracking was seen in previously produced grain on fat tanned skins, this is likely due to three factors: first, the role played by the enzymes present in the urine, which are known to produce a more flexible grain layer; second, the low levels of oxidation undergone by the neatsfoot oil (Thomson, 1991b; Haines, 1991c; Landmann, 1991). In the absence of this reaction, aldehydes are not produced, resulting in less grain cracking than seen in other grain-on fat tans; and three, the lubricating effect given to the grain layer by the heavier neatsfoot oil as opposed to that provided by lighter weight emulsified solutions such as brains. The defining characteristics and tendencies for urine tan can be viewed in Figure. 8.2-4.

Vegetable Tan (Bark Tan)

After rawhide, vegetable tan was perhaps the most distinctive tannage type. The vegetable tanned samples showed a number of very distinctive characteristics, which set this tannage type apart from the others. It is defined by a dense, full handle, seen even in samples which were in the bark solutions for less than a month. The most notable characteristics, unique to the bark tanned samples, were the lack of visible light transmitted through the samples, and the lack of florescence under UV light.

It is unlikely that the grain surface of vegetable tanned skins would have been intentionally removed, and this tannage type gave the grain surface a plump, robust look and feel with a significant amount of topography, especially in the thicker-skinned species. The oak bark solution imparted a dark, rich brown colour that is very distinctive to this tannage type. It should be noted that different plant species result in a variety of colours, and though most fall in the brown spectrum a few such as eucalyptus bark are reported to give much lighter colours.

The bark tan samples tended to show a tight fibre weave, with a moderate amount of fibre definition and separation. When viewed in cross section, vegetable tan was very compact, and appeared dense. It tended toward a moderate amount of splitting-up, a medium to high angle of weave, and a fibre network appearance dominated by small curves. Due to the tight nature of the fibre structure and the compactness, the vegetable tanned samples tended to be less pliable and have much less stretch than the fat tanned skins.

When the individual fibres were viewed they were full and rounded, with a dull lustre and no translucence. They were the only fibres which consistently showed this full, rounded appearance. The fibres tended to have a textured surface and an outline of gentle undulations.

Important behavioural characteristics seen on used items made from bark tanned skins included: very square edges, even on well-used lacing/thong, and holes with jagged points on the interior circumference. Holes subjected to stress show only a moderate level of stretch and tend to maintain points on the interior circumference. If the holes are punched as opposed to pushed, they have a tendency to stay very round and not stretch out into large ovals. The defining characteristics and tendencies for vegetable tan can be viewed in Figure. 8.2-5.

Alum Taw

Alum taw was the most difficult of the tannage types to distinguish, as most of its characteristics fell in between the two extremes of vegetable tan and the grain-off brain tans. The most defining characteristic of the alum tawed samples was the amount of stretch and pliability, which was maintained in spite of the intact grain layer. The amount of elasticity the grain layer exhibited was much greater than that of the other tannage types. The grain layer of this tannage type also produced the most distinctive follicle pattern.

Alum taw allowed visible light to pass through the samples, but, in the thicker skins, this was only visible in a room with dim light. This differed from the fat tans, in which even the thickest samples allowed visible light to pass through without interference. Alum taw reacted strongly to UV light both on the surface and in cross section.

The fibre structure of alum taw showed a tendency towards a moderate amount of fibre separation, definition and interwovenness. When viewed in cross section, it was compact and closer in appearance to the bark tanned cross sections than to cross section from the fat tanned samples. The fibre structure tended to have a medium to high angle of weave, and little splitting-up of the fibres.

When individual fibres were observed, they had a tendency to be more full and rounded than the very flat ribbon-like fibres seen in the fat tan, but not as plump as fibres from bark tanned samples. However, when the actual size was measured for two species, the fibres from alum taw and bark tan yielded similar measurements. Fibres from alum taw tended to have sheen, as opposed to being brightly shiny and reflective, as was seen with fat tanned fibres. The fibres did transmit light and had a tendency toward textured surfaces. Alum taw also appeared to produce an effect labelled 'crinkle', where the fibre's outline had a tight series of undulations.

Traces of use included moderately square edge morphology, and linear stress lines and grain cracking on lacing thong. The defining characteristics and tendencies for alum taw can be viewed in Figure. 8.2-6.

8.3 Preservation Environment and Exposure: What Survives?

There are, of course, limiting factors for the use of the tannage-determined characteristics outlined in this chapter. Most can be affected to varying degrees of severity by the depositional environment and the state of preservation. The better the state of preservation, the more likely it is that multiple indicators of tannage type will be identifiable.

Defining Characteristics		**Tendencies**
	Macroscopic	
Colour		Bright White to Cream
Surface Text- Grain	Full, Plump with a large amount of topography	
Surface Text- Flesh		Coarsely Fuzzy
Thickness		Middle range of species average
Pliability	Soft	
Static Stretch	Stretchy	
Fibre Rolls		Variable
Membrane Remnants		Few
Light Translucence	Yes (thick skin in dimmed light)	
UV Reactivity- Surface	Strong	
UV Reactivity- Cut edge	Strong	
	Microscopic	
Fibre Size		Upper end of species average
Fibre Definition		Moderate to Well Defined
Fibre Separation		Moderate Separation
Fibre Weave		Tight to Moderate
Fibre Fullness	Moderately Full	
Cross Section		
Compactness	Very to Moderately Compact	
Splitting-Up		Little to Moderate
Angle of Weave		Medium to High
Fibre Network Appearance		Small Curves
	Individual Fibre Appearance	
Fibre Outline	Crinkle	
Fibre Surface Texture		Textured
Fibre Lustre		Sheen
Fibre Translucence	Yes	
	In-Life Use Traces	
Edge Appearance	Moderately square	Some linear stretch lines
Hole Morphology	No information	

Figure 8.2-6. Alum Taw- Defining Characteristics and Tendencies.

Colour, while a very distinctive characteristic of each tannage type, is also the least likely characteristic to survive intact over the life of the object and its subsequent sojourn in the depositional environment. A case could be made, however, for colour as a clue to tannage type in some cases of dry site preservation, where the artefact has had little to no contact with water. The same might hold true for frozen sites, where the processed skin has been protected by the other extreme, though sun bleaching appears to be a factor which needs consideration when viewing items preserved in frozen sites. Many of those viewed in museum collections looked to have been affected by sun exposure. It is unknown whether or not this was before, during or after the items' encasement in snow and ice. It is the case with many of the glacier finds that the artefacts are exposed for various amounts of time after melting out of the receding ice.

In addition to particularly good preservation allowing colour to be used as an indication of possible tannage type, a site that provides multiple items from the same depositional environment may also allow colour to play a role in analysis. If different colours are found on skin products from the same depositional environment, there is a possibility that they were different colours before deposition as well. This could also be due to paints, stains or dyes, and, as mentioned in chapter 7 (manufacturing sequence), this would need to be ruled out, preferably by microscopic observations of cross sections.

Transparency in rawhide is another colouration trait which is unlikely to survive even the object's use life. When used, the minute flexing of the fibres within the rawhide item breaks the fibres apart slightly, making the interior more irregular. This scatters the light passing through, leading eventually to an opaque product. This process happens more quickly, and is more exaggerated, in areas which undergo the most movement. Often areas where there is little movement retain some of the original transparent character. Looking at these more fugitive characteristics as supporting information means that even characteristics as notoriously ephemeral and easily altered as colour can inform the assessment of processed skin artefacts.

As objects are seldom preserved entire, determining where the sample being looked at may have originally been located in the object, such as an elbow, an armpit, or the bottom of a bag, can be important in understanding the artefact as a whole item. Identifying the original context of the piece has implications for stretch, hole appearance and even the compactness and angle of the fibre structure, as these will differ significantly, for example, between a shoe upper and the sole

Surface texture can be affected both by use during the life of the object and, later, by the cleaning process during conservation. Processed skin is a fairly homogenous substance, and if subjected to the same interment environment it tends to degrade or not fairly evenly. That being said, one of the more delicate areas of the skin's structure is the interface between the grain layer and the underlying dermal thickness, called the mid-dermal junction. When grain-on (sometimes referred to as full thickness) skin products are interred in an environment where some bacterial action is able to take place, this area can break down more quickly than the surrounding dermal tissue, causing the grain layer to delaminate. This can also be caused by processed skin items being dried too quickly during the conservation process (Volken, pers. comm. 2013). Aside from delamination, one is not likely to see one side of the object in better shape than the other if all other variables are equal. If this is seen, it may be a clue in itself that the skin has had a surface treatment of some nature, possibly one containing tannins (which inhibit breakdown by microorganisms), or else that it was near or touching an item which assisted in its preservation, such as a metal object. (For more information on skin preservation in the presence of metal see Cameron (1991)).

Handle is another characteristic likely to be affected by preservation. The amount of pliability and stretch are of great help in ruling out rawhide and narrowing down the other tannage types. However, the original level of fibre movement is unlikely to be retained through to the present day. Nonetheless, some processed skin items retain a large measure of the original handle. This has been observed from frozen, wet and dry sites making this a more useful identification characteristic than originally thought. For items which have not been excavated in as well preserved a condition, inferences to the original pliability can still sometimes be made based on any folds present. An item which was originally very soft will have lain differently than a stiff piece of rawhide, and even after many years of compression may be visible. Another way of looking at an item is when the use of an item is obvious, such as with a shoe – the handle necessary to make that item function well can be taken into account. A shoe can have a certain amount of rigidity and still be perfectly functional, while a cloak or a trouser leg's function would be adversely affected if made from a stiff skin. Whilst not an iron-clad indicator of tannage type, this type of inference can, when combined with other characteristics, build a better idea of the original nature of the processed skin object being analysed.

The use of light translucence and UV reactivity in determining tannage type is of great value. The major preservation concern for this characteristic has to do with items which have come into contact with concentrations of tannins after their deposition into the archaeological record. This is notoriously the case with processed skin artefacts preserved in bog environments. The general consensus is that a bog environment produces an unintentional secondary vegetable tannage, making the original tannage type difficult or impossible to determine. Though some artefacts are likely to be over-tanned by deposition in a bog, bogs vary extensively in their chemical makeup, acidity, alkalinity and tannin content. In light of this, secondary tannage should not be assumed as a rule. Analysis of bog bodies has revealed that, surprisingly, vegetable tanning in the traditional sense of tannic acid, is not the preserving mechanism. It is instead more akin to pickling vegetables, in that the combination of a low Ph, low temperature and lack of oxygen allows the PH of the body's tissues and of its associated artefacts to lower to match that of the surrounding bog before putrefaction can begin (Fischer, 1998: 238). A second opinion on the preservation mechanism by Covington (2011: 455) states that preservation is due to a 'Maillard reaction between free amino groups in the proteins and reactive carbonyl groups in a soluble glucuronoglycan, sphagnan, containing residues of D-lyxo-5-hexosulopyranuronic acid'. This is the same reaction that is responsible for browning the outside of toast.

Unfortunately for UV reactivity, even a small amount of tannin douses the fluorescence of the surface of skin. Fat tanned items, over-dyed with tannin-based dyes (by immersing them in a solution), quenched the fluorescence through the full dermal thickness. Rawhide, however, with its dense structure and intact ground substance, may not allow tannins to migrate through to the centre of the dermis.

Light translucence was also negated by over-dyeing brain tanned objects. However, there is some evidence that this is not always the case in bog-preserved items. Very thin items which came from a bog context which when analysed, showed characteristics indicating they were originally rawhide still allowed light to show through when tested. None of the other preservation environments looked at during this research seemed to affect UV reactivity or light translucence unless the item was still covered in a layer of soil.

The ability to analyse the microscopic fibre structure is very much dependent on the state of preservation of the object. The less bacterial activity undergone, the more information the analysis of the dermal structure and fibres themselves can yield. There is the potential for the compression undergone by processed skin objects to skew the interpretation of the fibre structure, which makes the angle of weave appear lower, possibly producing a denser-looking cross section. However, compression cannot add substance to the empty, airy fibre structure of fat tanned skins, but can only make them thinner in cross section. One characteristic which may be more affected by preservation environment than the others is fullness. The fullness of the fibres has the potential to undergo change due to the pH of the depositional environment, as acidic or alkaline conditions are both capable of causing dermal fibres to swell.

8.4 Conservation: Impacts on Defining Characteristics

Aside from the concerns posed by the different preservation environments and their impact on tannage-based characteristics, a host of other variables had the potential to obscure these identifying characteristics. The time span over which the artefacts analysed for this research were excavated or collected covers well over a hundred years. The variety of conservation treatments used over this range of time was considerable. How these treatments could affect the assessment quality of an artefact was a primary concern. Heavy conservation treatments have the potential to obscure or even erase discriminating characteristics. Knowing the conservation history of the object being analysed can be helpful in deciding whether or not an observed characteristic is a product of a treatment applied after excavation, as opposed to one which may inform tannage type. Whilst modern conservation good practice records all conservation treatments, this was not always the case in the past. Thus, where some conservation treatment was recorded for material conserved from the 1950's onward, it cannot be assumed to be a complete record, and caution is always necessary. Items from early collectors may have no information at all.

The impact of various conservation techniques on the tannage identification traits is still in the early stages of research. That being said, some conservation practices, mainly from earlier periods, are likely to cause difficulties. Treatments such as humidification for reshaping an item, and dry brushing and vacuuming as cleaning methods, are unlikely to negatively affect traits used to identify tannage type. However, difficulty in assessing these traits can be caused by heavy consolidation treatments of the surfaces, or full thickness of a skin object. When applied sparingly to the surface, these treatments do not seem to compromise any identification features. However, if applied heavily, they can cause the surface and to some extent the cross section to appear denser than it would originally have looked. In one extreme example, a shoe had been so heavily treated it simply appeared plastic under magnification and maintained no hint of its original handle.

The over-application of leather dressings is perhaps the most commonly encountered (and likely easiest to avoid) condition seen by leather conservators (Fletcher pers. comm. May 2015). Processed skin items which have been very heavily coated with leather lubricants (which were added to restore a given amount of flexibility to stiff leather), are likely to cause difficulties for analysis as well as conservation. Over-application is likely to obscure diagnostic surface features such as the level of fibre separation and loft, and the reflective nature of the fibres. On a macroscopic level, it can drastically change the surface colour, and may affect how well subtle dendritic cracks, often seen on grain-on skin, can be perceived. It can also cause disastrous side effects such as oxidation and stiffening of the skin and encourage bio-deterioration. Solvents contained in many dressings can wet, swell and deform the leather (Kite *et. al.*, 2006: 128); all of which negatively impact the recognition of traits important to tannage identification. Even items conserved in the latter part of the 20th century can be prone to exhibiting 'spue', a white residue formed when the longer chained fatty acids, such as; carboxylic acids migrate to the surface of a leather object (Covington, 2011: 402). Sticky, oily deposits resulting from the application of early conservation treatments are another frequently encountered problem for conservators (Kite *et al*, 2006: 122).

While over-conservation is quite problematic for leather analysis, under-conservation, in the sense of leaving a skin item very dirty, can also hamper analytic efforts. The dirt trapped in the skin's fibre structure obscures the fibres from observation, and makes morphological traits such as edges, holes and linear stress lines difficult to see. A large amount of dirt on and in a skin object, also appears to affect the usefulness of UV reactivity and light translucence. However, achieving a reasonable level of cleaning during the conservation process mitigates these issues almost entirely.

'Conservation of Leather' provides an in-depth overview of the most frequently applied conservation treatments in use since 1982 (Kite and Thomson, 2006). Chapter 13 includes a list of cleaning, consolidation and lubrication agents used from 1982 thorough to the publication date in 2006. It is apparent from reading the recommendations that, the closer one gets to the present, the more emphasis there is placed on doing only what is absolutely necessary to conserve an object. This 'less is more' approach will certainly be welcomed by leather researchers, especially those who deal with new technological analysis, the results of which can be heavily impacted by the presence of conservation treatments. As analysis of the sample collections moves toward more sensitive analysis techniques such as mass spectrometry, IRF, X-ray florescence and any forthcoming techniques which can analyse the components of processed skin items, the deployment of these analysis techniques and interpretation of their results will require a firm understanding of current conservation protocols as well as access to information on past treatments.

8.5 Assessment of Preservation Contexts Based on Analysis of Museum Collections

8.5a Introduction to Preservation Contexts

The secondary aim of this research was to assess whether or not the discriminating characteristics associated with each tannage technology survive deposition, recovery, conservation, and storage. This portion of Chapter 8 seeks to illustrate the application of the methodology established previously in chapters 5, 6, and 7 by giving an overview of the archaeological and ethnographic items analysed to test the developed methodology on real world items with all their inherent challenges. Eight collections spanning two continents were chosen in order to observe artefacts from a wide range of preservation environments. The collections observed included artefacts preserved from dry, wet, frozen and more typical buried depositional contexts. These collections were carefully chosen to include an array of skin items which fell within the project's geographical and chronological boundaries as detailed in the introductory chapter. In total 85 skin items and four tools, from eight museums over two continents in five countries were observed for both macroscopic and microscopic traits associated with the various tannage technologies.

For ease of reference these are laid out by preservation context, region of origin and the museum in which they are housed in Figure. 8.5-1 and Figure. 8.5-2. The table first lists individually those items selected as case studies then gives a numerical summary of the items in regard to context, region and museum. A table detailing the 85 artefacts analysed organized by museum (Figure. 8.8-1) can be found at the end of this chapter.

Out of the total number of items analysed thirteen were selected as case studies, eleven archaeologically recovered and two ethnographic items, six from North America and seven from Europe. While these case studies were a part of the original thesis, due to copyright they will be forthcoming as individual papers in conjunction with each respective museum where they are housed. The items chosen as case studies are listed at the end of each section. These case studies were designed to showcase how the methodology can be applied. Each item was chosen because it was a solid example of a set of discriminating characteristics preserved from one of the depositional contexts in question, or because it answered a specific question. Most contexts have three case studies each and an effort was made to show different tannage technologies from each context if more than one type was encountered.

It was noted while searching museum catalogues for archaeological skin items with potential for analysis, that many of the ethnographic items encountered had little detail included in their descriptions concerning manufacturing sequence, tannage type, or construction materials. It became apparent that the method presented here could be useful to museums for ethnographic material as well. To assess the value of this approach for ethnographic items a number of objects were chosen for analysis alongside those from archaeological contexts.

The only museum where enough time was allotted to make this feasible was at the American National Museum of Natural History (NMNH) in Washington, DC. As detailed in the introduction chapter the ethnographic items had more direct relevance to North American archaeology however, many of these items came from groups living in very cold climates and cool dry climates which potentially lends them relevance to early periods of European prehistory. In addition, these items allowed 'in life' and 'in museum' factors to be assessed without having to account for complications from interment. For example, many of the skin items showed stiffening due to length of time in storage. In this way the ethnographic items became a fifth 'preservation context'. A single stand-alone case study (unhindered by copyright) of an ethnographically collected item is presented in Chapter 9 as an example of how the methodology can be applied.

As detailed previously, past conservation protocol and treatments varied extensively, and it was unknown how much these treatments would affect the visual and physical characteristics which form the basis of this

Case Study Items Catalogue Number and Location	Date	Archaeologically Recovered				Ethnographic
		Wet	Dry	Frozen	Burial	
Europe						
Assen 1962 II 207 C	Bronze Age	X				
Bern FNR 84676	4,215 + 55 BP			X		
Bern FNR 102385&84	3,945 ± 65 BP			X		
Copenhagen C5030	2227± 37 BP	X				
Oslo C56163	1420-1260 BC			X		
Oslo A2011-327	Viking				X	
Swindon White Horse Hill – uncatalogued	1900 -1500 BC	X				
North America						
Denver 0.1113.1	Ancestral Puebloan 1200 BC – AD 1350		X			
Denver 0.4442.1	Ancestral Puebloan 1200 BC – AD 1350		X			
Washington DC A564865-0	3295 BC-AD 520		X			
Washington DC A423371	Mound Builders AD 800 – 1450				X	
Washington DC 37631-0	AD 1879					X
Washington DC E76031	AD 1885					X

Figure 8.5-1. Table of Case Study Artefacts Analysed by Preservation Context.

Location	Archaeologically Recovered				Ethnographic
	Wet	Dry	Frozen	Burial	
Europe (Total: 34)					
Assen	9				
Bern			16		
Copenhagen	4				
Oslo			2	2	
Swindon	1				
North America (Total: 48)					
Cortez		3			
Denver		18			
Washington DC		4	5	7	11
Totals	**14**	**25**	**23**	**9**	**11**

Figure 8.5-2. Table of Museum Artefacts Analysed by Preservation Context. Numerical Summaries by Collection. Total Skin Items Analysed: 82*
*4 items observed were archaeologically recovered tools associated with leather working.

methodology. It was with great relief that only one item out of the 89 analysed was conserved in a way which made analysis impossible. This item was a shoe which was impregnated with a plastic-like glue to hold it together and allow it to be reshaped permanently into its more original foot-shaped form for display purposes. Aside from this extreme example, the only other difficulties encountered due to conservation choices were a few pieces from dry site contexts which still had a large amount of soil on the surfaces, and a few pieces which had been mounted for display by sandwiching them between plates of Plexiglas, which made them difficult to view and photograph due to an obscured surface and glare respectively.

8.6 Preservation Contexts

The sections that follow are grouped by preservation context. An overview of each context; dry, wet, frozen or ethnographic is given where any context specific concerns or revelations are mentioned.

Assessment of General Burial Contexts

The general burial category is best described as a common type of interment by which the artefact is buried either intentionally or unintentionally, but after burial the site is not permanently inundated with water, permanently frozen or permanently desiccated. The general category had in most cases the poorest preservation of the contexts encountered. Artefacts from contexts which did not fit well within the other four categories were often relegated to general burial category. As items in this category usually come from depositional contexts which are not dry and are not fully wet, but may instead be intermittently inundated, it is unusual that any skin artefacts survive at all. The nine artefacts encountered in this context were preserved by two different mechanisms; one contact with metal (in this case bronze), the others were likely preserved by a low oxygen environment. This anoxic environment was produced in two cases by the artefacts being buried in large grave mounds and in a third case by burial in a rubbish heap.

The general burial category is the most challenging to make any kind of general statements about due to the large differences in humidity, soil composition and antiquity of the depositional environments. This context was the most likely to have fat tans, rawhide and presumably alum taw (no alum taw was identified during analysis) gelatinize and disappear. Wet contexts which were not also bogs, so have no sphagnum moss present as a preserving agent, also suffered from this type of deterioration. This process of gelatinization is only visible if the item was hair-on originally. The hair would be left behind in the neat aligned order in which it was attached to the dermis, only the dermis is completely absent. In at least one, and possibly two, of the grave mound contexts the colour of the items was close to the original of what would have been expected for the identified tannage type. In the case of the hair-on items, which retained some of the dermis, the fur colour was also preserved – so much so that the patterns of colour originally worked into the item were visible.

Due to the generally poorer preservation in comparison to some of the other contexts, less of the distinguishing characteristics were identifiable on these items. However, interesting information could still be gained and in many cases the tannage technology was identified though with less confidence due to the incomplete nature of the sets of distinguishing characteristics.

Assessment of Dry Preservation Contexts

It is well known that dry sites produce artefacts with exceptional preservation. This is especially true of processed skin items, many of which are produced using tanning technologies which do not preserve well in wet or humid environments, due to these tannage type's susceptibility to bacterial attack when damp. With this in mind, access was requested to collections at 'History Colorado' in Denver, Colorado USA, The Anasazi Heritage Centre, outside of Dove Creek, Colorado and the National Museum of Natural History branch of the Smithsonian Institution, located in Washington DC. The Smithsonian objects were housed at the Museum Support Centre in Suitland Maryland, referred to as MSC hereafter. The author was privileged to be granted access to these three collections, which include a large number of items from dry preservation sites spanning a large portion of western North America. In Europe there are sets of artefacts from dry preservations sites, notably a large collection at the British museum, however these originate from areas such as Egypt which lie outside the geographical parameters set for this phase of this research.

There are a few observations specific to dry site preservation which were seen for many of the twenty-five items assessed. Dry preservation appears to preserve the colour, surface texture and handle of the artefacts to an impressive degree. So much so that in many cases both traits were able to be used as indicators of tannage technology. Light translucence, UV reactivity, and for rawhide, transparency, were all retained for the majority of the analysed objects. Microscopic characteristics were preserved to the same degree as the macroscopic traits, and due to this the fibre structures were able to be effectively assessed on most samples. In-life use traces were identifiable on many objects and could be used to inform not only tannage type, but in some cases object biographies as well. No items were encountered which had been conserved in such a way as to hinder analysis, however a few pieces were still covered in a heavy layer of soil and this obscured many of the surface characteristics.

Assessment of Wet Preservation Contexts

The exciting bog finds of northern Europe are well known. Bogs and other wet preservation sites such as lake sediments have produced some exceptional artefacts, no small portion of which have been items made of processed skin. Bags, belts, hats, cloaks, various utilitarian items and numerous shoes have been recovered (Hald, 1980; Larsson, 1990; Mannering *et al.*, 2010; Goubitz *et al.*, 2001). Access was requested and kindly granted to view items from the Drents Museum in Assen in the Netherlands, the National Museum of Denmark in Copenhagen, and Wiltshire and Swindon History Centre in Chippenham, in the United Kingdom to view specifically the material recovered from the Whitehorse Hill site, which was then being conserved by Helen Williams.

Fourteen items were assessed from wet preservation contexts, most of which were in a very good state of preservation. Based on these fourteen items some general statements can be made about wet site preservation and conservation and curation of items recovered from this context. The colour though altered by environmental factors, was interesting in that some items had differently coloured pieces on the same item making a case for the pieces being different colours originally as well. Surface texture seemed, once cleaned, to be close to that expected of the tannage technology suspected for the Item. However, pliability and stretch were adversely affected and most of the items assessed were likely stiffer and have a decreased amount of stretch than was present in their original state. Of the wet site items observed, the plasticised shoe and some finds of suspected vegetable tannage with delaminating grain layers posed the only conservation concerns. The delamination is possibly attributable to the items being dried too quickly or is a product of poor control during the tanning process.

Some observations were specific to items from bog sites. Both transparency (how clear vs opaque a material is) and translucency (the ability of material to allow light to pass through) were expected to be affected by bog preservation. The transparency of rawhide and the translucency of suspected fat tanned skins were compromised as expected. However, the translucency of rawhide was not always affected and in two cases visible light was still able to pass through the full dermal thickness. Skin items from bog sites have raised concerns as to the feasibility of identifying the original tanning methods used. It was thought that these items were likely to be compromised due to the secondary tannage they receive in the bog environment. Based on the analysis undertaken during this research, there is evidence suggesting that this over-tannage is not as straightforward as assumed. It may be that the bonding of the tannins to the collagen, as happens in vegetable tanning, does not occur in bogs at the degree or not in as consistent a way as was previously thought. This is an interesting development for tannage technology researchers.

While this determination has been made by assessing the distinguishing characteristics as a whole, in-life use traces have been leaned on more heavily for this preservation context compared to others, as a way to circumvent the secondary tannage dilemma. These in-life use traces are set in place during the life of an object, for example the shape of stitch holes and edges, which are less affected by changes undergone during interment. The analysis of the set of archaeological items preserved in wet sites showed that this type of preservation environment retained a large number of identification traits.

Assessment of Frozen Preservation Contexts

Many of the recent archaeological finds, which have captured media attention, have been a result of the slow retreat of permanent ice patches in mountain ranges around the world. While this occurrence signals a potentially harmful shift in the planet's ecology, it has been a bonanza for archaeology, especially concerning rarely preserved organic artefacts. These organic artefacts make up the 'missing majority' (as defined in Hurcombe, 2014) of the archaeological record, and when preserved by exceptional circumstances, allow a glimpse into a vastly more nuanced prehistory, and the individuals that inhabited it, than is often afforded by standard archaeological investigation. This exceptional preservation extends, on occasion, to processed skin artefacts. Skin items from frozen contexts, while encased in ice, are isolated from most taphonomic processes which complicate the identification of tannage type, such as bacterial attack and exposures to environmental tannins. This rare set of conditions makes these items especially well-suited to tannage type analysis.

Access to two sets of artefacts from frozen sites was requested and kindly granted. The first set were recovered from Schnidejoch Pass and were held by the Archaeological Service of the Canton of Bern, Switzerland. The second were held by the Museum of Cultural History in Oslo, Norway, and were recovered from a variety of Norway's receding ice patches. Some generalizations drawn from the twenty-three items observed from frozen contexts include colour again being more useful than expected. Aside from pieces which had obvious sun bleaching, earlier skin objects were a different and usually lighter colour than the later Roman and Medieval items recovered from the same context. They also had different surface textures and levels of pliability. While the surface textures seem to have survived with little obvious change, the level of pliability and stretch were impacted. This is likely due to the wet and dry cycle undergone by the items. This process will reduce the pliability of all tannage types if the dermal fibres are not manipulated during the drying process (Emmerich Kamper, 2019). Due to the fragility of many archaeologically recovered skin items, it is understood that this type of manipulation is unlikely to be feasible! Light translucence was maintained for many of the items observed though transparency was never noted in the rawhide items analysed. Most of the items labelled as rawhide appeared to be parts of shoes, so the amount of movement of the dermal fibres during the objects use makes this observation unsurprising. From a conservation standpoint, many of the frozen items had undergone very little treatment apart from being cleaned and very slowly dried, which meant that there was no question of surface textures or dermal fibre densities being impacted by surface applications of conservation treatments.

There were significant differences in the state of preservation between the twenty-three frozen site objects analysed often based on how long they were exposed after having melted from the ice. Fat tanned items and rawhide items were both present in the early material including the skin shoe which dates to approximately 3,400 BP and items from later time periods fulfilled the criteria for classic vegetable tan. However, the characteristics of a few of the items indicated a more unusual tannage type were not as straight forward. The ability to identify this is perhaps due to the exceptional preservation and the detail observable in these items. This context contained the earliest finds analysed for this research at more than 4,000 years old and included a scrap with seam holes and a patch from a complete legging. Several of the characteristics identified indicate the use of two tannage technologies on the same piece of processed skin. This made two of the three case studies chosen for this context excellent examples of possible combination tans or at least subtypes which are not as easy to identify and explore when seen in other preservation contexts.

Assessment of Ethnographically Collected Items

Many of the museums with collections of archaeological leather items also house large numbers of ethnographic objects. The potential usefulness of the methodology to provide information about ethnographic objects for museum collections had been considered. It was decided to test the methodology on these items as well as the original goal of archaeologically recovered items. As the NMNH housed a large ethnographic collection in the same facility (MSC) as the archaeological items being analysed, twelve of these objects were added to the list for assessment. The ethnographic items from the NMNH allowed the comparative photographic collection to expand to include species not easily acquired by the author, as well as new construction techniques and materials such as intestine which are not frequently encountered.

Ethnographic items also provided an analysis opportunity to study tannage types being used by groups during the early contact period in North America. Though the tannage technologies from these time periods were recorded, and still fall within the major tannage categories of mineral, vegetable, fat and smoke tannages, the chance to observe and analyse items which might incorporate variations of these tannage categories was a useful opportunity. In addition, many of the items were over a hundred years old, providing an opportunity to observe the effects of ageing on some of the tannage types, not complicated by the environmental factors associated with interment.

In general with the ethnographic material it was interesting to note macroscopic changes such as colour and handle, which had changed from those expected for a modern item made of a the same tannage type, since the amount of discolouration and stiffening due to age hardening (which would occur over time) for the different tannages was unknown. In general, there was an overall trend for stored items to be stiffer than would be expected for the item in its original condition. Colour appeared little changed based on the interior of folds or bags being a similar colour to exposed surfaces. It is assumed that most of the items have been housed away from bright light. When put under gentle tension many items which should originally have had stretch, still retained at least some measure of this trait. Light translucence or the lack thereof, and the transparency of rawhide items had not been affected by the length of storage. Those pieces able to be analysed for microscopic traits, proved to have sets of microscopic characteristics which closely matched those of the tannage type suspected based on macroscopic observations. There were no conservation practices encountered which impacted the analysis potential of any of the ethnographic items. Due to the lack of interment, the identification of traits which indicated tannage type was less complicated for the ethnographic items than for the archaeological equivalents. This made some of the items assessed a very close match for traits identified in the modern sample collection. Practical details are not often recorded for many ethnographic objects and identifying tannage types and construction techniques brought the life history of these objects to the fore, adding a layer of information not often available for museum objects acquired from early collectors. This method is a potentially valuable tool for museums and opens an avenue for much larger scale analysis as a future project.

As detailed in the introduction chapter, these ethnographic items are more directly applicable to North American archaeological items however the questions of ageing and conservation are more broadly relevant. Many of the environments where the ethnographic items studied were produced and used, prior to the availability of commercial tanning options, mirror that of environments present in various periods of European prehistory. This makes some crossover in interpretation possible concerning the available resources for tanning and which tanning technologies might function well in a given set of environmental conditions.

8.7 Summary of the Preservation of Discriminating Traits

Based on the 85 artefacts analysed from various preservation contexts, the general observations specific to each can be summarized as follows:

- General Burial preserved discriminating traits poorly, however this varied rather drastically by burial environment. As the fur was not often in contact with environmental tannins fur appears to have retained a measure of its original colour. If large amounts of iron were present in the soil discolouration of both fur and dermal tissue was observed.
- Very dry environments preserved all the discriminating traits used for identification of tannage type very well, and many pieces could be mistaken for recently made items. Handle was the only characteristic to show some change, with a number of items losing a measure of flexibility over time.
- Wet environments preserved in-life use traces well, and surface texture and fibre structure appear to retain an appearance similar to what would be expected from a recently tanned skin surface and cross section. Colour and handle were both adversely affected in most items observed from wet sites, with most skin items stiffening after drying, and all skin items observed being a (most likely) darker colour than when originally processed.
- Frozen environments had preservation similar to dry sites, in that nearly all the discriminating tannage identification traits were preserved, including fibre structure and surface textures. Colour appeared to be moderately affected, with sun bleaching apparent on a number of artefacts. Handle was the characteristic most affected by frozen preservation. This is unsurprising, as most of the artefacts have gotten wet either before freezing or during the thawing process and have dried in a stiffer condition than would likely have been the case when new.
- Ethnographic items were interesting in that, as expected, most of the identification traits were well preserved. However, over time, most of the items had stiffened. This change in handle was most severe in historic vegetable tanned items but affected the fat tannages to varying degrees as well.

8.8 Conclusion

Besides these general observations, colour as a discriminating trait is worth discussing individually. It was somewhat surprising how well colour was preserved in many of the items analysed. As mentioned earlier, colour can be fugitive, and is easily altered by environmental factors. However, from the observations made during field work, dry sites appear to preserve colour in such a state that it can be used as a reliable indicator of tannage type. The colours seen in dry site objects made from various tannage types closely matched the range of colours that would be expected from the same tannage type, had the skin items been newly made.

Glacial preservation also appears to preserve colour true to expectations for each tannage type, with some lightening due to sun bleaching. The level of sun bleaching can be discerned by comparing all surfaces, as the surfaces protected from sunlight in folds, and those facing the ground, will likely retain the original colour of the object prior to UV exposure.

Though wet sites definitely changed the original colour of the preserved objects, they did not completely obscure all differences in colour. Some objects retained more than one colour of fur and differing flesh side surface colours which implies that these pieces were almost certainly different colours prior to deposition, during the use life of the object.

In summary while thousands of years do take their toll on the objects being observed, more information was recoverable than was originally expected. This information goes beyond the identification of tannage technologies and can provide information about many aspects of the object's construction, use and, sometimes, reuse. The approach reveals information on both tannage type and on the object biography. The summaries of the discriminating characteristics, identified in the sample collection, provide a working methodology for the analysis of processed skin, and objects made from it. Each tannage technology has been assessed as a whole and the differences between subtypes detailed. The possible impacts of preservation and conservation have been considered in the light of current research and personal experience. In chapter 9 these summaries of discriminating characteristics are applied to a stand-alone case study of a complex ethnographic artefact to highlight the applicability of the methodology on an artefact containing a broad range of species and tannage technologies.

8.9 List of All Museum Artefacts Analysed

Archaeological Material							
Museum Location	Catalogue Number	Radiocarbon Date	Period	Preservation Environment	No. of Pictures	Description	Accession Notes
Assen	1878 VI 6		Iron Age <	Bog	35	Shoe	
Assen	1951 I		Roman	Bog	25	Roman Purse	
Assen	1961 IX 6 B		Roman	Bog	56	Patched Shoe	
Assen	1962 II 207		Bronze Age	Bog	56	Shoe	
Assen	1962 II 207 A&B		Bronze Age	Bog	31	Emmer man Cloak Edge	
Assen	1962 II 207 C		Bronze Age	Bog	35	Emmer man Cap	
Assen	2010 II 1		Bronze Age	Bog	54	Frag. Of Main Cloak/ Cape	
Assen	BC1 1991 I25	800-600 BC		Bog	56	Gathered Toe Shoe	
Assen	BC2 1991 I26	1400-1200 BC	Bronze Age	Bog	16	Heavy Additive Shoe	
Bern	FNR 108 388 L10229	4,160 ± 35 BP	Neolithic	Glacier	32	Med Brown Fragment	
Bern	FNR 116 110	4410 ± 35 BP	Neolithic	Glacier	43	Thick Multi Piece Shoe	
Bern	FNR 84676	4,215 ± 55 BP	Neolithic	Glacier	55	frag. G patch from Legging	
Bern	FNR 84680 Lnr4194			Glacier	32		
Bern	FNR 90055 L4097	1,195 & 1,230 ± 50 BP	Roman	Glacier	30	Dark Brown Roman Shoe	
Bern	FNR 90076 L4183	4,265 ± 55 BP	Neolithic	Glacier	34	Shoe with Loops Still Attached	
Bern	FNR 90094 L4184			Glacier	2	Loin Cloth Fragment	
Bern	FNR 101026 L8780	3,450 ± 50 BP	Neolithic	Glacier	39	Horse Shoe Shaped Gathered Shoe Piece	
Bern	FNR 102385&84 L9458&57	3,945 ± 65 BP	Neolithic	Glacier	38		
Bern	FNR 102408 L9469	3965 ± 55 BP	Neolithic	Glacier	29	Thin Stiff Yellowish Piece	
Bern	FNR 125338 L14654	2nd 1/2 14th century	Medieval	Glacier	28	Sole Leather Probably Roman	
Bern	FRN 14640			Glacier	8	Reddish Hair Lotschen Pass	
Bern	FRN 100993 L8782	1,650 ± 50 BP	Roman	Glacier	25	Dark Brown Rows of Holes	
Bern	FRN 102454 L9510			Glacier	22	Flexible Piece of Strap	
Bern	FRN 125320 L14636			Glacier	34	Cream Coloured Thong	
Bern	FZ 101044 L8994			Glacier	9	Super thin Raw Hide	
Copenhagen	D2624-26			Bog	6	Ronbjerg Strap with possible impression	
Copenhagen	C H Cape?			Bog	15	Skin Cape with fine stitch work	
Copenhagen	C5030	2227± 37 BP		Bog	31	Vindum Mose cape	
Copenhagen	C5742	2149 ± 22 BP		Bog	34	Havndals Mose Shoe	
Cortez	78.2.2713		Ancestral Puebloan	Dry Cave	17	Fragment from Beaver Creek Cave 1	
Cortez	78.57.5RB1463.45.1		Ancestral Puebloan	Dry Cave	23	Fragment	
Cortez	2000.19.48		BasketmakerIII Pueblo III	Dry Cave	32	Quiver	

Figure 8.9-1. Table of Museum Artefacts Analysed. Total Museums: 8; Total Artefacts: 86; Date Range: 4400 BP- 1800s; Neolithic = 15, Bronze Age = 7, Iron Age =5, N.A. Prehistoric = 41, N. American Ethnographic=12, Undefined=6; Total Pictures: 2139.

Archaeological Material							
Museum Location	**Catalogue Number**	**Radiocarbon Date**	**Period**	**Preservation Environment**	**No. of Pictures**	**Description**	**Accession Notes**
Denver	0.841.1		Ancestral Puebloan	Dry Cave	32	Striped Hide Fragment	
Denver	0.1098.A		Ancestral Puebloan	Dry	25	fragment from 2 different species	
Denver	0.1098.B		Ancestral Puebloan	Dry	22	Skin frag poss. basket impress.	
Denver	0.1098.C		Ancestral Puebloan	Dry	18	Part of ABC previous Set of 23 pcs	
Denver	0.1101.1		Ancestral Puebloan	Dry	10	Shaved? Post dep. Hair loss	
Denver	0.1106.1		Ancestral Puebloan	Dry	20	Rawhide (rodent?)	
Denver	0.1108.1		Ancestral Puebloan	Dry	15	Elk?	
Denver	0.1109.1		Ancestral Puebloan	Dry	26	frame holes, tool marks	
Denver	0.1110.1		Ancestral Puebloan	Dry	30	Large, seams on 3 sides	
Denver	0.1111.1		Ancestral Puebloan	Dry	37	sandal sole with rodent tail	
Denver	0.1112.1		Ancestral Puebloan	Dry	25	Hide cap with ears	
Denver	0.1113.1		Ancestral Puebloan	Dry	25	1/2 rodent rawhide dried bag	
Denver	0.1114.1		Ancestral Puebloan	Dry	25	Fox? Face/hide bag	
Denver	0.1116.1		Ancestral Puebloan	Dry	19	Small bag grain on tied shut	
Denver	0.1158.1		Ancestral Puebloan	Dry	18	Sandal sole well-worn 3hole grain	
Denver	0.1159.1		Ancestral Puebloan	Dry	14	Red Squirrel? stuffed w/grass RH	
Denver	0.4433.1		Ancestral Puebloan	Dry	23	Hide frag	
Denver	0.4442.1		Ancestral Puebloan	Dry	17	Very well-tanned thin Fragment	
Oslo	4941			Burial, Bronze + Anaerobic	27	Big thin skin piece Rawhide	
Oslo	C5787	430-540 AD	Viking	Glacier	108	Triangular piece of stitched skin	
Oslo	C56163	1420-1260 BC	Bronze Age	Glacier	69	Skin Shoe	
Oslo	A2011-327		Viking	Burial	31	Net-Pack-Thong Thing	
Swindon	Uncatalogued at time of analysis			Wet/Bog	65	skin and cloth item	
Washington DC	A133060-0				9	Thick Strips	
Washington DC	A135941-0				12	Red Leather Strip	
Washington DC	A201035				3	Moccasin Last? (sandal weaving template)	
Washington DC	A212861				6	Bone Hide working tool	
Washington DC	A231892				3	Cannon Bone Tool	
Washington DC	A312270-0			Dry	10	Bag Fragment	Navajo National Monument / Tsegi Canyon, Arizona
Washington DC	A347617-0			Frozen/Permafrost	14	Seal Skin Harpoon	Alaska, Gambell St. Lawrence Island

Figure 8.9-1. Table continued.

Archaeological Material							
Museum Location	**Catalogue Number**	**Radiocarbon Date**	**Period**	**Preservation Environment**	**No. of Pictures**	**Description**	**Accession Notes**
Washington DC	A399553-0		Eskimo	Frozen/Permafrost	11	Eskimo Boot Fragment	Alaska, Barrow Quad, Barrow near Birnirk
Washington DC	A401502		Eskimo	Frozen/Permafrost	14	Eskimo Bucket Rim Fragment	Alaska, Nuvuwaruk
Washington DC	A411261				3	Worm	
Washington DC	A423371		Mound Builders	Burial Anaerobic	22	Spiro Squirrel fabric	
Washington DC	A423378-10		Mound Builders	Burial Anaerobic	21	Frag. Metal Preservation	
Washington DC	A448920-0		Mound Builders	Burial Anaerobic	21	Dark Brown Fragment	
Washington DC	A448934-07				11	preserved hair off skin between plexi-glass	
Washington DC	A504949			Burial/Refuse Pile	12	Green stained skin fragment	South Dakota, Oahe Reservoir
Washington DC	A506631			Burial/Refuse Pile	7	Dark Brown large item, Felt?	North Dakota
Washington DC	A506666-0			Burial/Refuse Pile	5	Dark Brown Frag. Felt?	North Dakota
Washington DC	A564865-0		3295 BC – 520 AD	Dry Cave	20	Cat skin Frag	Mexico, Cuatro Ceinegas, Fat Burro Cave
Washington DC	A565564-0		Prehistoric	Dry Cave	18	Grey skin Fragment	Mexico, Cuatro Ceinegas, Frightful Cave
Ethnographic Material							

Ethnographic Material							
Museum Location	**Catalogue Number**	**Museum Accession Date**	**Period**	**Preservation Environment**	**No. of Pictures**	**Description**	**Accession Notes**
Washington DC	E14601-0		Historic	Ethnographic	16	Paiute, Head dress with 'horns'	USA, Southern Utah
Washington DC	E33736-0		Historic	Ethnographic	20	Eskimo Sling	USA, Alaska, Eskimo
Washington DC	E034137		Historic	Ethnographic	15	Seal Flipper? Or just skin fragment	
Washington DC	E37631-0	1879	Historic	Ethnographic	31	Fish, seal, leather sack	USA, Alaska, Norton Sound
Washington DC	E76031	1885	Historic	Ethnographic	22	Sling, Pima, patched with veg. tan	USA, Arizona
Washington DC	E089395-0		Historic	Ethnographic	10	Hide Thimbles and bone needles	USA, Alaska, Eskimo
Washington DC	E90029-0	9 Jan 1884	Historic	Ethnographic	25	Bird net of skin thongs	Canada, Quebec, Ungava bay
Washington DC	E90030-0	9 Jan 1884	Historic	Ethnographic	14	Leather Belt Hair on	Canada, Quebec, Ungava bay
Washington DC	E115387	1885	Historic	Ethnographic	6	Leather Bag, Goshute	Utah, Juab County, Deep Creek
Washington DC	E310007	16 August 1919	Historic	Ethnographic	10	Bone Hide working tool	Russia, Siberia, Habarovsk
Washington DC	E405228-0	30 August 1966	Historic	Ethnographic	13	Rawhide bottle, Ute	Colorado, Southern Ute Res., Ignacio
Washington DC	Gut comparison material		Historic	Ethnographic	52	Pics of Yellow and White Gut from Alaska	Eskimo

Figure 8.9-1. Table continued.

Chapter 9

Case Study of Ethnographically Collected Container

9.1 Introduction

One of the twelve ethnographic items observed is presented here as a stand-alone case study. This item showcases a large range of species and multiple tannage types used in its construction. This item also provided insight into the age-related questions concerning handle for three different tannage technologies (rawhide, fat-tan and vegetable tan) and several subtypes, including suspected rub-on vegetable tan and grain-on fat tan.

9.2 Artefact Analysis for MSC Catalogue Number E37631-0 (Processed Skin Container)

Catalogue number E37631-0 consists of an ornate bag made from processed skin, collected and donated by Edward W. Nelson. It was collected from Norton Sound, Alaska and though it has no collection date, it has a museum accession date of 1879, making it now 140 years old. As is often the case, the item's description is vague – it is described as a 'fish skin and leather sack made from dressed skin'. This bag was chosen as a case study due to the wide variety of species, material types and tannages incorporated into a single item. Seal skin treated two different ways, at least two species of fish skin, an unidentified collagen-based material, cervid hair, sinew, and what the author believes is baleen make up the various elements of this bag.

The overall handle of the bag is flexible, but the different elements have differing qualities including colour, surface texture, and handle, and are best discussed individually.

The spotted fish skins which make up some of the linear band designs in the bag are easily identified as fish by the distinctive scale marks on the grain side and the cross hatched fibre pattern of the flesh side (Figure. 9.2-2a and Figure. 9.2-3d). The colouration pattern points to these skins belonging to Char (*Salvelinus alpinus*) (Rahme, 2006: 25). These elements have a slightly papery feel, however, based on the morphology of the holes, the skins were soft enough when new to sew without the holes tearing around the circumference. The holes show no overstretching, nor do they tightly form to the thread, indicating that the bag was sewn when the skin elements were dry, and that it is unlikely that that bag has been wetted often, if ever, after construction. The holes near the edge or rim of the container have retained soft points on the inner circumference, where the awl or needle was used to push holes through the skin. As the characteristics of this element match best with fat tannage the fact that these points are still visible indicates that this area of the item was not under any constant stress. When microscopically photographed with the light shining from underneath, the spotted fish skin strips were translucent and allowed visible light through indicating that this element has not come into contact with tannins. Due to the intact state of this object, cross sections were not possible as there were no exposed edges. Based on the light translucence, hole morphology and the general handle of the spotted fish skin elements, they are most likely a fat tannage, and when new had a reasonable degree of softness.

Figure 9.2-1. Catalogue Number E37631-0: Container made from processed seal, caribou and fish skin with cervid hair and baleen embroidery.

The fine red bands used as contrasting edging for the white bands are also fish, but the skin has been positioned flesh side out. The flesh side has been coloured a red, with the red dye likely made from willow (*Salix sp.*) or alder (*Alnus sp.*) bark (Figure. 9.2-2c and 9.2-2d). These species are both available in the area where the bag was collected, and their used is ethnographically documented (Oakes and Riewe, 1995; Reed, 2005; Charles, 2005; Issenman, 2011). These bark dyes are suspected as the red strips allow no light transmission through the skin an indicator that the skin has come in contact with tannins. Though, the use of ochre is also a possibility as a heavy application also obscures light transmission. However, there is no mineral element (grit) observable in the fibre structure. The dye or stain on these elements was applied as a surface treatment as opposed to a dye bath, based on areas where abrasion has occurred. In these areas the colouration has noticeably rubbed off leaving the lighter, original colour exposed.

The dull red linear strip located between the two middle bands of white material has also been treated with tannins and allows no light transmission (Figure. 9.2-3b). This strip is made from dehaired seal skin, where the hair was likely slipped (as no roots are evident) and shows a well-preserved grain surface. This grain pattern matched other museum items viewed, which were listed as being made from seal skin (Figure. 9.2-3c). The sample collection does not currently contain a seal skin for comparison as it is illegal to possess this species in the UK. This skin section is duller in colour than the red fish skin, but the dye appears to have been more thoroughly applied, possibly via a dye bath as opposed to being rubbed on. It is visible on both sides and is very even across the grain surface. This surface is not smooth, and if it were rubbed on, one might expect to see more pigment in the lower areas in contrast to the high points. Due to its placement within the design there was no way to view a cross section and neither edges nor holes could be observed on this part of the construction.

Some assumptions can be made about the level of softness of this element, as it would need to be reasonably consistent with the rest of the skins to maintain the pattern and handle of the piece. Seal skin is of medium thickness and this piece of skin would have most likely been well softened, in order to allow it to be sewn into the design. Without the ability to view the cross section, the question of whether the pigment was applied to the strip as part of the tanning process, or as a surface treatment, cannot be definitively answered.

The large bottom piece comprising the base of the bucket or bottom of the bag was also seal skin, based on comparisons with other museum items. It was difficult to access the interior bottom of the bag to determine

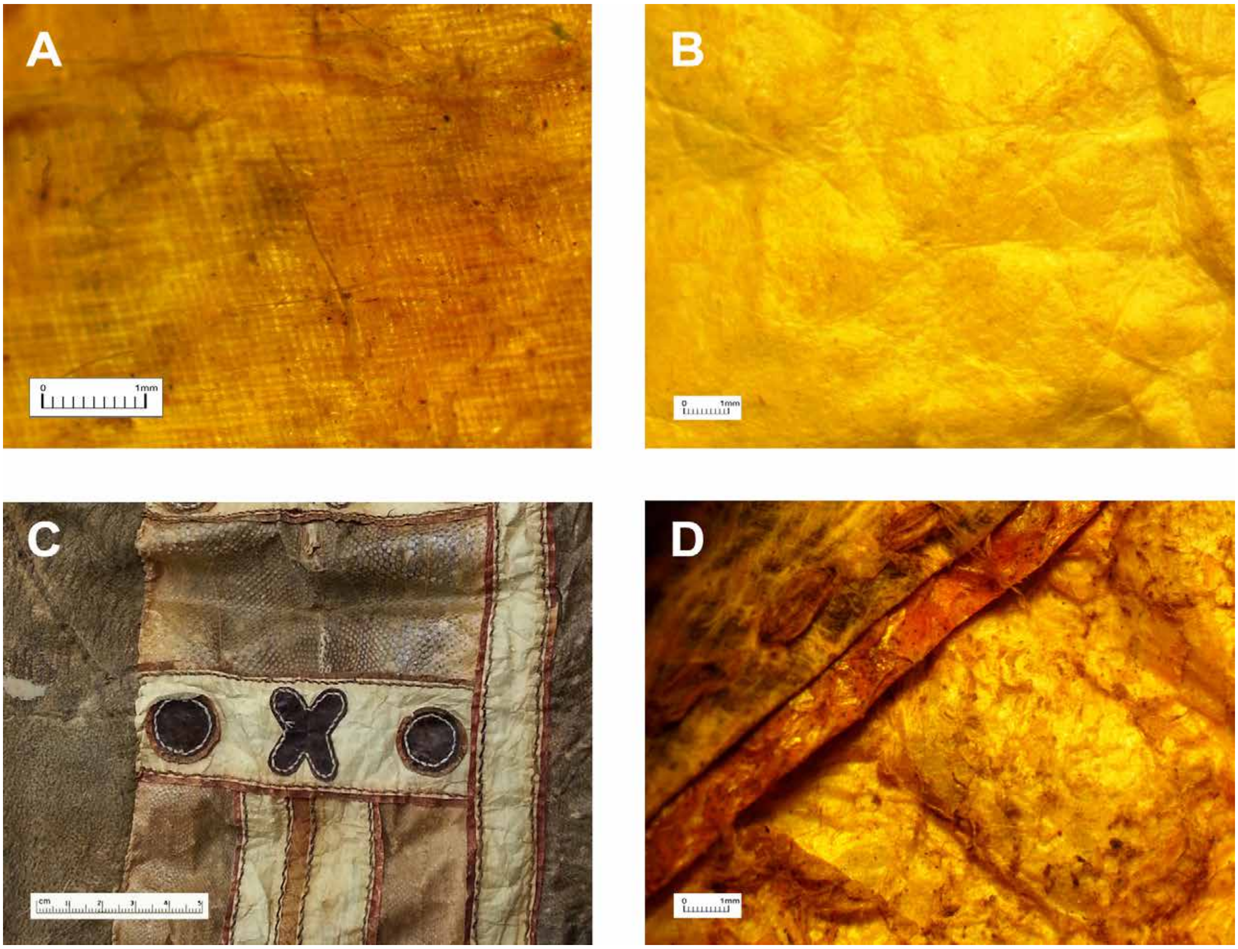


Figure 9.2-2. Details of E37631-0: **A**- Fish skin (flesh side) showing cross hatch fibre structure, **B**- Close of smooth (grain?) side surface of white bands, **C**- Detail of contrasting colours and textures, **D**- Close up of red skin strips and white skin bands showing the textured (flesh) side surface and fish skin. Original Magnification: A-30x, B, D-10x, C-0x.

the grain side vs flesh side, as the bag had stiffened over time (Figure. 9.2-1). However, based on the appearance of the more visible side, the outside surface of the bucket appears to be the grain side with the grain removed. Light transmission through this part of the skin was unable to be assessed, as a single layer of the bottom portion could not be accessed. The handle was moderately soft, and still retained the feeling of loft when gently pressed. The surface had a texture more similar to the fat tanned samples than the vegetable tanned samples. The surface fibres were defined and well separated and were flat and reflective as seen in fat tannage. However, no cross section analysis was possible, as there were no exposed edges.

The stitching on this part of the bag uses twisted sinew and was incredibly finely done, with up to ten stitches per centimetre. The holes had formed to the thread, in keeping with the characteristics of a well softened fat tan. The skin was a dark tan in colour. The slight greyish undertone is also characteristic of older fat tanned skins and tends to become more pronounced the more heavily used an item is. Based on these characteristics, the seal skin on the bottom portion of the bag is most likely a fat tannage. Whether or not the skin was smoked as part of the tanning process is difficult to determine. If light translucence could be assessed, and it did transmit light, then the darker colour of the skin is likely attributable to smoking. However, it could also be attributable to the species. Seal contain a large portion of intradermal grease which after oxidizing gives the skin a yellowish tone. This grease is seldom fully removed in the arctic traditions of tanning as leaving some percentage in place improves water resistance and lessens the work needed to soften the dermal fibres (Oakes and Riewe, 1995; Issenman, 2011).

The white bands used in the design could be either white gut skin or dehaired and bleached skin. The grain side had a smoothly textured surface with no visible follicles or hair roots – a surface which looks very similar to white gut skin (Figure. 9.2-2b). However, the inside surface

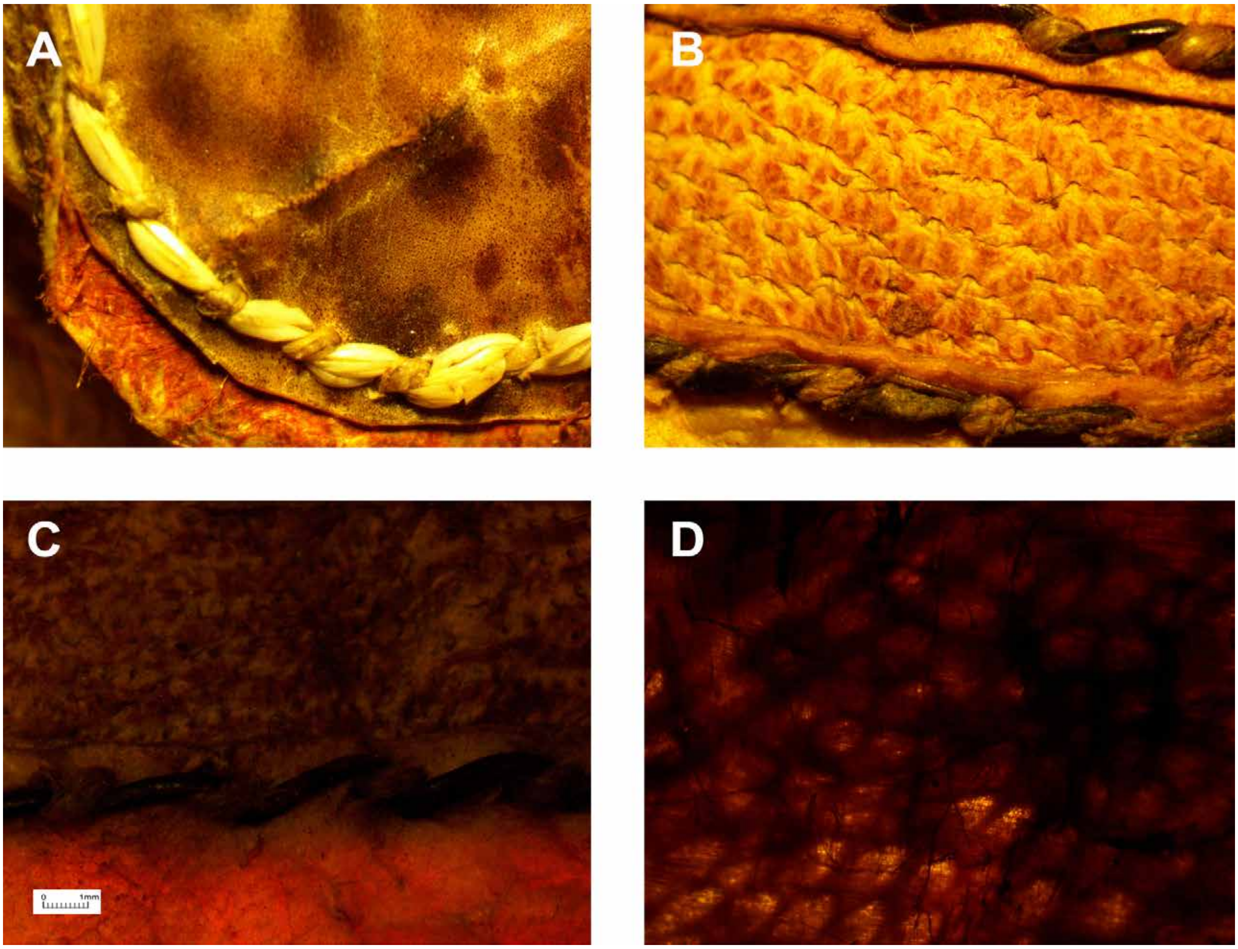


Figure 9.2-3. Details of E37631-0: **A**- Dogfish skin circle with deer hair embroidery, **B**- Detail of dull red skin bands with possible baleen embroidery material, **C**- Red Band showing no light translucence (top) next to the white band which does allow light through (bot), F- Fish skin (grain side) showing scale pattern.
Original Magnification: A-D-10x.

of the white strips was more fibrous in appearance than the inner surface of the gut skin samples observed at MSC. When looked at with light from underneath this element also a lack of discernible fibre structure. The material has not been treated with any solution containing tannins and was translucent when viewed using bottom light. Along the length of the white band just to the inside of the edge, a dark piece of what the author believes to be baleen is sewn down with sinew. The shiny black embroidery which maybe made of baleen contrasts sharply against the white skin. Again, the stitch work is very fine, and the few holes that can be observed have formed to the sinew thread, further supporting a fat tanned or simply manually softened product.

The applique pieces used to form the circles and X's on the middle panel of the bag are quite intricate (Figure. 9.2-2c). The middle piece of each motif has a stiff handle and, based on the scale pattern and coloration, may be spotted wolfish skin when compared to sample pictures in Rahme, 2006 (page 22). The outer decorative border is the same flesh side up, dyed red fish skin described earlier as edging the white bands. Each motif is also outlined just inside its circumference, with very white hair belonging to a cervid (Figure. 9.2-3a). Both moose (Alces alces) and caribou (*Rangifer tarandus*) do inhabit the Norton Sound area and both are known to have been used for this circumpolar variety of surface decoration (Speck, 1911).

The complexity of this object highlights the ways in which the different tannage types, species and materials can be used, not just for the differing behavioural properties, but also for the aesthetic differences, combining the variety of surface textures and colours into a visually appealing piece of artwork that is also a functional piece of household gear. Detailed photographs showing a selection of the traits and characteristics discussed above can be seen in Figure. 9.2-1, 9.2-2 and 9.2-3.

Chapter 10

Discussion and Conclusion

10.1 Completion of Original Aims and Objectives

The original aims laid out for this research are addressed in turn:

1. The production of a reference sample collection, comprised of skins from species of key prehistoric importance; each processed using six tannage types, which are widely documented ethnographically, and could be achieved using technology available prehistorically.

In practice, the tannage types chosen and used to produce the sample collection were: vegetable tan, alum taw, wet and dry scrape brain tan, urine tan, and rawhide. The species selected and sourced included nearly all the big game animals from North America and Europe, as well as a significant representation of traditional furbearing species.

2. The analysis of the sample collection to develop a systematic method for the identification of tannage types, using commonly available technology (microscopy) to identify traits unique to, or indicative of, each individual tannage type.

This was documented, and key characteristics were identified for the tannage types, though some were found to be more distinctive than others. In addition, in-life use traces were found to be a very useful diagnostic tool.

3. Testing the developed methodology on museum collections of processed skin objects, which have been archeologically recovered from a variety of preservation environments, to discern whether or not the discriminating traits indicative of each tannage type survive.

After examining numerous museum objects it was found that the discriminating traits do survive, and can be used as reliable indicators of tannage type, though this is dependent on the items state of preservation.

4. The clarification of terminology used by differing sets of leather/processed skin enthusiasts, to foster better communication between the various groups for future collaboration.

It is hoped that this research has made a start in the clarification of at least some terminology associated with animal skin processing. It is also hoped that better communication will lead to less distance between leather researchers, modern tanners, traditional tanners, and the community of craft practice surrounding tanning and leather working.

Over the course of this project, a wide range of tannage technologies and varieties within these technologies were researched. This research helped to inform the choice of tannages selected for use in the project and was based on which varieties had the widest use ethnographically. A similar process, based on archaeological evidence, was used to select the species to be included in the sample collection. Though a few notable species, such as wolf, were unable to be sourced, 23 of the selected species were acquired from a wide geographical area, and a sample collection consisting of, at present, 155 samples was produced.

The sample collection was analysed, and macroscopic traits such as handle, surface texture and colour differences noted. Further analysis at a microscopic level was undertaken for the surfaces, cross sections and individual fibres. These observations allowed the identification of discriminating traits associated with each tannage type, though the identification at the technology level is more definitive than attempting to differentiate between varieties of the same tannage type. For example, differentiating between rawhide, fat tannage, vegetable tannage and mineral tannage is more definitive than attempting to tell dry scrape brain tan apart from wet scrape brain tan, or either of these apart from urine tan.

After analysis, the discriminating traits were organised and recorded to provide a systematic method for the identification of tannage type. This method was then used to analyse a selection of processed skin artefacts, housed in museum collections across the USA and Europe. Numerous artefacts were examined from a range of preservation environments, and all of the preservation contexts encountered preserved at least some discriminating characteristics. This produced a large data set for further analysis and raised a number of questions about the preservation seen between the varieties of interment contexts. Questions such as how much UV light travels through ice or snow, and how long does sun bleaching take if the item is exposed, as opposed to, still encased in ice or snow, will provide a number of avenues for future research.

A unanticipated result came from the examination of the author's reference collection of modern clothing, which is made from traditionally processed skins. The various behavioural tendencies of the different tannage types produced very different patterns of hole and edge shapes, after an item had been in use. These 'in-life use traces' were also affected by the treatment of the skin during the object's manufacturing process (*i.e.* rawhide worked damp or dry), and by the different conditions and circumstances the object was exposed to during its use life. These findings allowed the interpretation of small sections of the chaîne opératoire, for both archaeologically recovered and ethnographically collected objects. The discovery that this method could be used to add information, on that kind of level, to an item's object biography has tremendous potential for future research!

10.2 Future Directions for Research

This research focused exclusively on microscopic analysis of surface, cross section and individual fibre features for the identification of tannage type. There are, of course, other methods of analysis relevant to this identification process. Shrinkage temperature, various mass spectrometry methods, lipid analysis, and plant phenol identification all have merit and potential to add to our knowledge of the origins of tannage technologies. In the future, funding will be sought to continue this research using more technologically advanced analysis methods for the identification of tannage types and, potentially, even individual ingredients, using the sample collection as a starting point. In addition to using the current reference collection to investigate other more sophisticated methods of analysis, there are plans to expand the sample collection.

Modern tannages were left out of this research, as they were inapplicable to the time frame outlined for this research. However, to have a more complete guide to tannage identification, they should be included at a later date, as items made from early chrome tans (latter part of the 19th century) have begun to appear in small numbers in museum collections. A second addition will be the inclusion of more skins from small game. Rodents, lagomorphs, and more localised furbearers are currently underrepresented in the reference collection, in comparison to their representation in the archaeological and ethnographic record.

Expanding the reference collection of clothing and utilitarian items made from traditionally processed skins is also an important future goal, and one that will be worked toward in cooperation with other ancient technologists, living history interpreters, and modern users of traditional tannage technologies. The current clothing and utilitarian item collection has provided a starting point for the classification of edge and hole morphology, and the various wear characteristics. More objects from known tannage types, with recorded histories of use, are needed to document the range of variability seen due to thickness or other, as yet unidentified, factors.

This is an agenda in which cooperation between researchers and re-enactment, or primitive/traditional technology groups, is hugely beneficial. It is unrealistic for a single researcher to generate the amount of use, which an item of clothing or utilitarian object needs to sustain, in order to produce comparative collections of wear-based characteristics. However, these groups of individuals wear clothing and shoes, and use various bags, belts, straps and miscellaneous items made from processed skin, for long periods of time. They are used in a variety of weather conditions, and for a large range of different activities, allowing them to acquire patinas and stains from sweat, food, charcoal, and smoke, likely to be seen in archaeological equivalents. Greater interaction between researchers and re-enactment groups has the potential to provide data not available in any other way and allow access to a collection of items with unique characteristics unlikely to be available from other sources.

An additional avenue of research was noted when tool marks were observed on the grain side of a skin dried and processed in a frame. These striations formed when the skin was de-grained using stone tools and were similar to those seen on historical and archaeological items. They form in a less prominent way when a skin is de-fleshed in a frame using stone tools. None have been noted when using serrated bone tools for de-fleshing in a frame, or when using unserrated bone tools for de-fleshing and de-graining over a beam. Further controlled experimental studies need to be undertaken to solidify these observations. It would be exciting if manufacturing methodologies could be observed in this way!

10.3 Critical Reflection

While a basic technique has been established during this project for the identification of tannage technologies, augmented by in life-use traces used to track the object's biography, some aspects of the project, upon reflection, could have been more successful. The most significant of these were the burial experiments implemented early in the project. Initially, two methods were planned for testing whether or not the discriminating traits for tannage types survived in the archaeological record. One was the examination of museum collections, the second was a small-scale burial experiment.

A few small samples of each tannage type were interred in three burial contexts: a perennially wet marsh, a pine forest verge, and flat alluvial plain (now a housing complex). Each burial site was photographed, and a tent peg placed in the ground to mark the location. However, after the allotted three-year period, none of the samples were able to be recovered, even with the help of a metal detector. While this was a disappointing result, the examination of the museum objects showed that discriminating traits do indeed survive. While it would have been useful to have the burial results to supplement the museum observations, it was understood from the beginning that such a small experiment would be far from definitive. These types of interment experiments are important in establishing parameters for the preservation of discriminating traits, and it is understood that a more systematic set of actualistic and laboratory-based experiments would be needed and can be designed as part of a future project.

A second issue, while not a failing of the research, is the lack of a grain pattern comparison section in the analysis. Though the identification of species was not one of the goals of the research, and there are now more certain ways of species identification (DNA and Proteomics), it was an area of interest for all of the museums visited. A grain pattern comparison chart, especially of the more unusual species contained in the collection, would be a useful addition for further analysis work.

10.4 Concluding Statements

It was hoped that this research would culminate in a 'user's guide' to the identification of tannage types used in prehistory. Though the contents and data from this project have been consolidated and analysed in a way which produces such a guide, it is not as straightforward as I had hoped at the start. The use of the micrographs as a comparison guide, as well as the actual observation and analysis of leather materials, can require a reasonable amount of experience to accomplish successfully. However, with a bit of practice, the method is not only feasible, but is returning very interesting information about not only tannage type, but everything from manufacturing sequences to the conditions in which an artefact may have been used. Though any of the discussed identifying characteristics can be produced by multiple causes, when looked at comprehensively, they can give a reliable idea of the tannage type used to produce the skin item in question.

This information, alongside the object biographies provided by in-life use traces, can provide a wealth of information from even small fragments of recovered skin items. With enough fragments, a better picture of the variety of methods used in traditional skin working can be assembled. This variety was, I feel, highlighted by the Inuit bag analysed at the National Museum of Natural History in Washington DC, in the USA. The incredible variety of this piece, with the number of variations of tannage technologies and material types it contained, from just one small geographical area, showcases the complexity of local tanning and manufacturing traditions. This complexity is what is so often lacking in our understanding of prehistory. It is what colours in the broad lines sketched by technology and culture-based discourse, and moves archaeology that much closer to the groups, and ultimately individuals, who made the past their home.

Appendix 1: Blank recording form for discriminating traits

Defining Characteristics and Tendencies:	
Defining Characteristics	**Tendencies**
Macroscopic	
Colour	
Surface Text- Grain	
Surface Text- Flesh	
Thickness	
Pliability	
Static Stretch	
Fibre Rolls	
Membrane Remnants	
Light Translucence	
UV Reactivity- Surface	
UV Reactivity- Cut edge	
Microscopic	
Fibre Size	
Fibre Definition	
Fibre Separation	
Fibre Weave	
Fibre Fullness	
Cross Section	
Compactness	
Splitting-Up	
Angle of Weave	
Fibre Network Appearance	
Individual Fibre Appearance	
Fibre Outline	
Fibre Surface Texture	
Fibre Lustre	
Fibre Translucence	
In-Life Use Traces	
Edge Appearance	
Hole Morphology	

Glossary of Terms Used in Text

A

Alum Taw: Immersion in an aqueous solution of Alum and common salt, which works best if kept between 20 ° and 38° C. The tawed skins are then left to dry until the alum salts crust. After ageing in this state, the skin is damped back, oiled (traditionally using egg yolks) and worked over a blunt edge (staked) until dry and supple.

Alkaline Solution: Solution most often made from potassium hydroxide (KOH), sodium hydroxide (lye), or calcium hydroxide (lime), mixed with water. Used to slip the hair and clean out the ground substance from between the fibres of the dermal network.

B

Bating: An enzymatic process used to degrade the non-structural proteins, such as elastin, the removal of which allows the grain to flatten and relax to a greater degree, increasing the square footage of the skin, as well as producing a softer product. These enzymes were originally introduced to the skin via an aqueous solution of liquidised faeces, most often from dogs (puering) or birds (mastering). A plant-based alternative uses fermented bran to produce the solution and was referred to as 'drenching'. (Covington, 2011, pg. 166-176).

Beam: (or Tanner's Beam) A smooth length of rounded material (wood, plastic, metal), often a log split down its length, or, for small diameter beams, a full log, over which a skin is placed to be de-fleshed, de-haired, scudded or de-membraned. A beam can be set up so that the tanner uses a pulling motion with the beam leaned against a stable wall or tree, or placed on a tripod so the tanner can pin the skin between their waist and the beam and employ a pushing action, dependent on the tanner's preference.

Brain Tan: See Fat/Oil Tan

Bucking Solution: See Alkaline Solution

C

Cable: (Noun) a length of twisted steel cable, braided rawhide or braided rope, suspended either horizontally or vertically between two objects, over which the skin can be stretched and abraded.

Cabling: (Verb) to work the skin over the cable to stretch the fibres and abrade the surface, which aides in drying the skin and the warmth helps to oxidize the lipids present.

Case Hardened: A condition where a vegetable tanned skin is placed into a tannin solution initially, which fills the outer layers of the skin with tannin, creating a barrier that prevents tannin from reaching the middle of the skin. The term can also be applied to skins (usually thick skins) which are dried too quickly in the sun. If the outsides harden before the inside is also dry, the interior area can rot.

Case Skinned: The skin is removed from the carcass by means of an incision made from the ventral opening out to each back leg. The skin is then carefully pulled down the body toward the head, in a manner similar to turning a sock inside out. This method is often employed for furbearers, whose belly fur differs significantly in colour and density to the back and side fur. This allows for these differing/contrasting fur sections to be cut apart as a whole after the fur is tanned.

Corium: See Dermis

Chamois: See Oil Tan

Cure: A term applied to any technique which stabilises a skin so it can be kept for a period of time before being tanned, such as drying, salting, brining or pickling.

Crust: A term usually applied to a skin which has been through a tanning process and allowed to dry hard, *e.g.* 'crust' leather.

D

De-fleshing: Removing the muscle and adipose tissue. The fascia, membranes and connective tissue which attach the dermis to the underlying strata are often removed at this stage as well. (See Membraning)

De-hairing: The removal of the hair or fur through controlled bacterial activity (sweating), the application of or immersion in an alkaline solution (slipping), or by manual means such as scraping or shaving. In the case of alkaline solutions, lye (sodium hydroxide), lime (calcium hydroxide) or KOH (potassium hydroxide) can be used. Prehistorically, it is likely that when an alkaline solution was made, it was done so by leaching wood ashes, which produces potassium hydroxide. The ashes can also be rubbed thickly onto the skin, which produces the same result, with a slightly slower process.

De-graining: De-graining, or graining, is a term used to describe the removal of the epidermis and hyper dermis (grain layer) by cutting or scraping it off with a sharp tool, or pulling or pushing it off using a dull tool. This separates or splits the finer upper layer of fibres (grain layer/papillary layer) from the thicker fibres of the Middle Dermis or Corium layer, using a combination of downward pressure and linear strokes. This term is most commonly seen in descriptions and discussions of modern traditional Brain Tanning (See Fat/Oil Tan)

De`gras´: 'A semisolid emulsion produced by the treatment of certain skins with oxidized fish oil, which extracts their soluble albuminoids. It was formerly solely a by-product of chamois leather manufacture, but is now made for its own sake, being valuable as a dressing for hides.' (Webster's Revised Unabridged Dictionary, published 1913 by C. & G. Merriam Co.**)**

Drenching: See Bating

Dry Scrape: Technique where the flesh and, depending on the skin's intended use, the hair and grain as well, are removed using a sharp tool when the hide is completely dry (usually done with the hide in a frame).

E

Epidermis: The thin outer layer of cells, which progressively move up from the sub-epidermal layers of the skin, eventually reaching the skin's surface, where they are shed. This layer is removed in any tannage where a hair off skin is desired. (Reed 1972, FAO 1960)

Epidermal Junction: A thin layer composed of ground substance and containing no fibres, which sits above the papillary layer and below the epidermis. The epidermis is separated at this junction either by bacterial activity or through chemical processes when the skin is de-haired. (Reed 1972, Haines 1991, Rahme 2001)

F

Fat/Oil Tan: A technology where the raw skin is de-fleshed and optionally de-haired and/or de-grained, after which emulsified lipids are added to the skin to lubricate the fibres as it is worked dry. Various levels of lipid oxidation occur depending on the types used and how much warmth is created during the dressing and softening processes. The oxidation of lipids, creates aldehydic compounds. The product is a very soft leather with a cream colour, which can hold 800% water, and after drying can be resoftened. (see chapter 4 section 4.3 for more detail). This tan is frequently combined with smoke tanning to produce a more useable product in terms of resistance to decay, insects and repeated washing.

Flat Skinned: Where the skin is taken from the carcass by means of an incision starting at the ventral opening and extending to the underside of the lower jaw. Connecting incisions, starting at the central cut, extend out along the inside of each of the four legs and around the ankles, allowing the skin to be removed as a flat piece. The head and feet can be skinned out and left attached as if desired.

Flint: A flint is a skin from a larger animal such as a deer, which is not commonly used with the hair on. It will usually have been de-fleshed and dried without the addition of salt. Also 'flint dried' meaning dried without salt.

Fleshing: See De-fleshing

Frame: A round, or three- or four-sided configuration made from rigid material, into which a skin is laced. The skin can then be de-fleshed, de-haired, oiled and worked, or simply left to dry. A technique often employed for large skins to make them more manageable, as they are often very heavy, or for furs to reduce the amount of disturbance to the fur side.

Frame working: Softening a skin laced into a frame.

G

Grain layer: The layer of very finely interwoven fibres which extends from the skin's outer surface to the base of the hair roots, and contains the hair follicles, sebaceous and sweat glands. This layer is alternately called the upper dermis, corium minor and papillary layer (Reed 1972, Haines 1991, Covington 2011)

Graining: See De-graining

Grain on/off: A skin where the grain remains intact, or where the grain has been removed, respectively.

Grain corium junction: See Mid-dermal junction.

Ground Substance: The chemically complex matrix surrounding the dermal fibres. It is a viscous substance composed of mucus, sugars, proteins and lipids – this medium is hydrophobic and if not removed impedes the uptake of tanning and dressing solutions. This medium is partially responsible for the rigidity seen in rawhide products. As the term mucopolysacharide and protein matrix is rather long-winded, the term Ground Substance was used by Reed (1972), and has been adopted by many modern traditional tanners. (Richards 2004, Rahme 2001, Haines 1991)

H

Handle: the feel of goods, especially textiles, when handled. This term is used here in to refer to how a tannage type feels: the drape and loft, as well as the density of the fibre structure when touched and handled. This includes the level of softness, recorded on a scale of very soft to very stiff.

Hair on/off: Skin tanned with the hair on or with it taken off, respectively.

Hide: Hide is a term used commercially and historically to refer to large thick skins such as cow, oxen and horse. For the purposes of this research, and in keeping with earlier publications, it will be used interchangeably with skins, a word typically used to refer to small thin skins such as goat or deer. The designation between the two terms is not relevant to this research, and the general size and thickness are obvious, as the species being discussed is always included.

Hypodermis: The layers of fibre in the skin which 'run in a horizontal plane to form a limiting or flesh layer, separating the skin form the underlying muscles.' (Haines, 1991 pg.1) When de-fleshing occurs, this is the layer at which the underlying flesh, membrane and adipose tissue are separated from the dermis. The adhesion of the subcutaneous tissues to this hypodermal layer varies in tenacity between species.

I

J

K

L

Latigo: Rawhide treated with oil after it is mostly dried, then minimally worked. Used for braiding lariat ropes and fancy horse tack in South America. Distinct from Dongola leather (which is sometimes referred to as latigo), which is a combination tan of alum and Gambier (pan tropical plants of the genus uncaria {http://en.wikipedia.org/wiki/Uncaria} which contain high levels of Catechins). This leather is used for saddle cinches and other outdoor uses, where tough durable leather is needed.

Leather: A skin product which meets the criteria of chemical stability, resistance to attack when wet by microorganisms and enzymes, retaining in the dry state the original fibre structure, and a higher shrinkage temperature when wet than that exhibited by raw skin. (Sykes 1991) However, in common parlance, it is taken to mean an opaque animal skin product, with a handle exhibiting varying degrees of suppleness.

Liming: See Alkaline Solution

Limiting layer: The limiting layer is the lowest layer of the Dermis, where the fibres become finer and run horizontal to the underlying musculature. This forms the limiting or flesh layer, which separates the subcutaneous tissue from the dermis (Haines 1991). During the defleshing and/or membraning steps, the subcutaneous tissue is shorn away at this junction. This process varies in difficulty dependent on species.

M

Mechanically Softened Product: A processed skin item where the dermal matrix has been softened without the addition of any dressing solution. Used most often for very thin skinned species or species with large amounts of endogenous intra-dermal fats/oils. Often associated with Arctic tanning traditions.

Membraning: The removal of subcutaneous or hypodermal connective tissue at the limiting or flesh layer, if not fully removed during the de-fleshing process. This is often done after the de-hairing process or, in the case of vegetable tan, can be done after being in the light tannin solution (first bath) for a few days. (See Limiting Layer)

Mid-dermal Junction: The area of the skin where the fine, densely-fibred grain layer gradually changes to the more coarsely-fibred mid-dermis, composed of fibre bundles which cross at a higher angle than those in the grain layer.

Mid-Dermis: The middle layer of the skin, which sits between the grain and hypodermal layers. This is also called the corium, reticular or fibre network layer in many tanning manuals, and is the layer which gives processed skin its strength and elasticity. (Reed 1972, Haines 1991)

N

Nap: The fuzzy surface texture of a tanned skin. Often used when talking about suede leather where the grain side has been sanded to a soft, fuzzy finish. For this research, it is used to talk about the fuzzy texture of (generally) the grain side of fat tanned skins, which have had the grain removed.

O

Oil Tan: The commercial terminology used to denote a tannage using oils which oxidise at low temperatures, mostly of marine origin, notably cod oil. The skins are drummed with the oil while the temperature is gradually increased, causing the oils to oxidise, creating aldehydic compounds which coat the dermal fibres. The product is a very soft leather with a slightly yellow colour, which can hold 800% water, and after drying can be easily resoftened. Also called Chamois leather.

P

Pelt: 1- A pelt is a term used to describe a furbearing animal's de-fleshed and dried skin, which can be salted or unsalted. This is used frequently when talking about beaver trapping, and is likely a familiar term to those acquainted with the Mountain Man or Rendezvous era of North American history. 2- This term can be, and often is, used to describe any animal's skin that has been minimally processed. For the purpose of this research, definition 1 will be used.

Q

R

Rawhide: The name used for a specific skin product that has been fleshed and often de-haired (slipped using lye, controlled bacterial activity, or shaved,) then rinsed (or neutralised if lye or lime were used) and dried. Parchment is a well-known variety that is produced using a specialised form of rawhide processing. Parfleche is another well-known type of rawhide product from the North American Great Plains. Rawhide is stiff, opaque or translucent depending on the tension it is dried under, and semi-resistant to water absorption due to the hardened nature of the ground substance. Rawhide can be oiled to increase its water resistance.

Raw Skin: A skin freshly taken from a carcass that has not yet been de-fleshed, salted or dried. From a prehistoric preservation standpoint, it is very unlikely that a skin would not be de-fleshed before being dried. Skins dried without first being fleshed not only attract insects, but are also at risk of grease burning (a condition where the rancid grease destroys the dermal integrity). This method of preservation is only viable in very dry environments, out of direct sunlight. (See PELT, and FLINT)

S

Skin: See HIDE

Skin Working: A generalised term used to designate the construction of goods from processed skins. Often seen used in reference to glovers, belt and shoe makers and furriers.

Skin Processing: A term used to denote the preservation and manipulation of animal skins to prevent decay, and produce a material which is suited to a required task.

Subcutaneous: See Hypodermis

Smoke or Aldehyde Tan: Where a skin is exposed to warm or cold smoke, forming cross linkages between the fibres, which renders it washable. Smoked fat tan can be washed with no ill effects to the tannage and with little impact on the handle of the skin, as long as it is not washed with detergent or exposed to very hot drying temperatures.

Staking: A term used to describe working a skin soft using a dull, broad edged tool to manipulate the dermal fibres in all directions. This can be done with a handheld tool or over a stationary tool, often set in a post sunk into the ground at about waist height. The latter tool is likely whence the term came.

Slip(ing): The process of a skin losing its hair through intentional processes or general decomposition. See Alkaline Solution and Sweating.

Scud(ding): Cleaning the hair follicles by pushing out dirt and oil trapped in them, using a round-edged tool, which squeezes out the impurities when used with the skin placed on a hard smooth surface. Normally associated with thick skins such as cow or oxen, and undertaken before immersion in the tanning solutions and after de-hairing is complete.

Sweat(ing): Using a controlled rotting process to slip the hair as a method of removal.

T

Tannins: Polyphenolic compounds obtained from various plant tissues (bark, leaves, roots, galls, etc).

Condensed: Catechol- 'vegetable tannin with a flavonoid structure' (Covington 2011, pg. xxv). These tannins produce a green black stain when combined with iron salts, and leather made using these tannins darkens and reddens when exposed to sunlight.

Hydrolysable: Pyrogallol- 'tannin based on saccharide esterified by polyphenol' (Covington 2011, pg. xxviii). These tannins produce a blue black stain when combined with iron salts, leather tanned using these tannins does not react when exposed to sunlight.

Tannage Type: Synonymous with Technology.

Technique: A method for accomplishing any step of the tanning process, such as dry de-fleshing, wet de-hairing, or working a skin soft over a stake.

Technology: In this case, a technology is the definition of a specific tannage type or group such as Vegetable Tan, Mineral Tan, Fat Tan, Acid Tan, or Rawhide.

Tawing: See Alum Taw

U

Urine Tan: Uric acid helps to break down and clean out the ground substance between the dermal fibres, which are then filled with lipids from subsequent applications of fat or vegetable oil. It is then worked soft using methods such as staking from the flesh side and hand pulling, which will not damage the intact grain layer.

V

Vegetable Tan: Tannins from bark, seed pods, leaves, galls or other vegetable materials (typically suspended in an aqueous solution) slowly penetrate the hide, cross-linking and coating the collagen fibres, making the hide more heat- and water-resistant, denser and less vulnerable to bacterial decay. Some forms of vegetable tanning use tannin containing plants, which are rubbed on both sides of the skin, which is then rolled up and left to absorb the tannins (Beyries, 2008). There is a more limited amount of tannins present using this technique, and full penetration is difficult to achieve, especially on thick skins. This technique results in a skin that has much more tannin in the outer layers than the interior. The extreme version of this is called case hardening.

W

Working: Defined here as the manual or mechanical manipulation of the dermal fibres to prevent the fibres from stiffening and locking together due to remaining ground substance. (*e.g.* 'working a skin soft').

Wet Scrape: Technique where the flesh and, depending on the skin's intended use, the hair and grain as well, are removed using a dull tool, keeping the hide wet at all times.

X

Y

Z

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DETERMINING PREHISTORIC SKIN PROCESSING TECHNOLOGIES

The importance of skin processing technologies in the history and expansion of humankind cannot be overstated, yet these technologies can be difficult to identify in the archaeological record. This research outlines the development of a systematic, non-destructive method for identifying the tanning technologies used to produce prehistoric skin artefacts. The approach combines extensive archaeological research and over 25 years of the author's personal tanning experience.

The method employs observations of an extensive sample reference collection, both macroscopic and microscopic, to produce a database of defining characteristics for six tannage types, from a large geographic area and time frame. The primary collection contains 22 species identified as economically important from both Europe and North America. A secondary collection of clothing and utilitarian items, made from traditionally processed skins, was used to add 'in-life use' traces to the database. The method was tested against both archaeological items from a variety of preservation contexts, and ethnographic items from museum collections across North America and Europe. This analysis confirmed that defining characteristics do exist between the primary tannage technologies, and that at least some defining characteristics survived in all preservation contexts. These can be recorded at multiple levels of observation, and often provide insight into small sections of the artefact's production sequence and life history.

This research shows definitively that processed skin items from vastly different preservation contexts can provide a wealth of information about prehistoric tannage technologies, as well as information on manufacturing sequences and the conditions of use an item experienced. The method is a valuable analytical tool for those involved in conservation, curation or analysis of archaeological or ethnographic skin products. It provides a consolidated source of information for artisans working with traditional tanning, or re-enactors interested in the history or science of skin products. Finally, it serves as an example of the targeted use of experimental archaeology in a large-scale research project, and will be beneficial to anyone involved in experimental or experiential archaeology.

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