

Tannage technologies available for clothing in prehistory

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Zusammenfassung

Gerbetechnologien für Kleidung in der Vorgeschichte

Die Bedeutung von Technologien zur Verarbeitung von Häuten für die Geschichte und die Verbreitung der Menschheit auf dem Planeten kann gar nicht hoch genug eingeschätzt werden. Frühe Gerbetechnologien sind oft schwer zu identifizieren, aber das Wissen darüber ist sowohl archäologisch nützlich als auch für die Konservierung von Artefakten von Bedeutung. Dieser Beitrag beschreibt eine systematische Analyseverfahren, die auf diesen speziellen Materialtyp ausgerichtet ist, mit dem Ziel, die in der Vorgeschichte verwendeten Gerbetechniken anhand von archäologischen Funden aus verarbeiteten Häuten zu bestimmen. Die Methodik ist das Ergebnis makroskopischer und mikroskopischer Beobachtungen an einer Referenzsammlung mit über 200 Proben. Diese wurden verwendet, um eine Datenbank mit definierenden Merkmalen von und Hinweisen auf jedes der sechs gängigen Gerbverfahren zu erstellen: nasses und trockenes Hirngerbverfahren, Rindengerbung, Alaungerbung, Uringerbung und Rohleder. Die Mustersammlung umfasst 22 ökonomisch bedeutende Spezies aus Europa und Nordamerika sowie eine Sammlung von häufig benutzten Kleidungsstücken und Gebrauchsgegenständen, die traditionell aus verarbeiteten Häuten hergestellt wurden.

Diese Forschung hat gezeigt, dass archäologische Funde aus verarbeiteten Häuten Aufschluss über die in der Vorgeschichte verwendeten Gerbetechnologien sowie detailliertere Informationen zu Herstellungsabläufen und Nutzungsbedingungen, denen ein Objekt unterworfen war, geben können.

Schlagwörter Prähistorisches Leder, Pelz, Hautverarbeitung, Häute, Gerbetechnologie

Introduction

Clothing is amongst the rarest of archaeological finds and yet it is a fundamental part of human material culture and a necessity in many climates. In the USA, where the author Theresa Emmerich Kamper was raised, the process of tanning is still part of traditional knowledge. Her background as a traditional tanner led her into academia to research the time-depth of this ancient skill. She realised that although archaeological leather was being researched, a standardised method for identifying early tannage technologies was unavailable. Using extensive archaeological research and practical experiments drawing on over 25 years of her tanning

Summary

The importance of skin processing technologies in the history and dispersal of humankind around the planet cannot be overstated. Past tanning technologies can be hard to identify, yet the knowledge is both archaeologically useful and can inform the conservation and ongoing curation of artefacts. This contribution outlines a method of systematic analysis targeted at this specific material type, with the goal of determining the tanning technologies in use during prehistory from extant archaeologically recovered processed skin objects. The methodology is a product of macroscopic and microscopic observations of a sample reference collection containing over 200 samples. These were used to produce a database of defining characteristics and tendencies for each of six tannage types: wet and dry scrape brain tan, bark tan, alum tan, urine tan and rawhide. The sample collection comprises 22 economically important species from Europe and North America, as well as a collection of well-used clothing and utilitarian items made from traditionally processed skins.

This research has demonstrated that archaeologically preserved objects made from processed skin can provide information about the tannage technologies used during prehistory, as well as more detailed information such as manufacturing sequences and the conditions of use to which an object was subjected.

Keywords Prehistoric leather, fur, skin processing, hides, tanning technology

experience, she developed a new method to distinguish prehistoric tannage technologies so that their time-depth and distribution could be better understood (Emmerich Kamper 2020). The second author Linda Hurcombe researches prehistoric artefacts and experimental archaeology and takes a special interest in perishable material culture, which she terms 'the missing majority' (Hurcombe 2007; Hurcombe 2014).

For this paper, these complementary interests serve to present the practical aspects of tanning technologies for Stone Age clothing. The authors are actively researching collections where this approach proves useful. The topic crosses archaeological interest in clothing for prehistorians, curators, and conservators.

Available prehistoric skin processing technologies		
	Chemistry	Behavioural characteristics
Rawhide	Skin that has been fleshed, slipped (de-haired using lye or controlled bacterial activity), or shaved, then rinsed and dried.	Stiff, shrinks up to 30 % as it dries, can be heat shaped or cold formed, can be made opaque or translucent.
Fat emulsion processed leather	Lipids are introduced to spaces in the dermal network where, depending on the saturation level of the lipid and the warmth produced during the softening process, oxidise to various degrees. This oxidation produces aldehydic compounds which react with the collagen matrix, supporting the collagen structure, and preventing its collapse and the re-sticking of the fibres which would accompany this collapse (Covington 2011, 317).	Soft, very flexible, stretchy, windproof, washable, water permeable, resistant to mild alkaline and acid (sweat).
Vegetable tanned leather	Tannins suspended in aqueous solutions slowly penetrate the hide. 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; Khanbaaee/van Ree 2001; Reed 1972; Reed 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 capillary structure (Reed 1972, 78).	Flexible, little stretch, dense, wind proof, can be treated to be water resistant, resistant to heat, can be heat shaped, invulnerable to bacterial decay. Is more susceptible to acid rot (i.e. sweat) and thin skins tear more easily than emulsion processed leathers.

Tab. 1 Available skin processing technologies in prehistory and their behavioural characteristics.

Tab. 1 *Verfügbare Hautverarbeitungstechnologien in der Vorgeschichte und ihre Verhaltenseigenschaften.*

Clothing provides protection from environmental conditions and bodily harm whilst also providing a powerful means of conveying social identities. Processing leather for clothing is a highly specialised subset of an extensive range of uses for processed skins. The tanning technologies utilised must produce material that is both soft enough to wear and able to remain so despite repeated wet and dry cycles. Producing clothing is likely to have been a significant factor in the day-to-day lives of ancient peoples. This has historically been an overlooked and underappreciated archaeological technology in part due to difficulties of preservation and in discerning traces of production, apart from investigation of use-wear traces which have led to ethnographic documentation (e.g. Audoin-Rouzeau/Beyries 2002; Beyries 2008; Beyries et al. 2024).

Whilst much has been written on skins, fur, and leathers, most of the available literature has focused on topics such as animal species, patterns, stitching, and decoration rather than how the skin was processed or has focussed on more recent tanning technologies, which better adhere to the parameters for modern definitions of leather (Calnan/Haines 1991; Thomson 2006). In contrast, the emphasis here is on the more ancient, more consolidated skin processing technologies. By ›more consolidated‹, we mean that processes that are separated into individual steps in modern tanning practice are instead, in traditional methods, consolidated into one or two processes.

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‹. This contribution aims to 1) provide an overview of available skin processing technologies for the time period, 2) outline the practical steps and choices within these technologies, and 3) explain the behavioural characteristics each tanning technology provides for making functional clothing.

Methodology

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. Previous research (Emmerich Kamper 2020) outlines the archaeological evidence for extant rawhide and fat-emulsion processed leather (from 10 000 years ago to the present), with skin processed using vegetable tannins as a much later technology in Europe (from 4000–5000 years ago to the present). A brief outline of these three processing technologies is shown in Tab. 1.

The 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, the appearance of archaeological skin products often can discourage interest and research in the subject in favour of more visually appealing commonly found artefacts. What has been lacking for these items is solid identification of the tanning technologies.

The method developed (Emmerich Kamper 2020) helps to fill this information gap by providing a systematic and standardised way of analysing and discussing these technologies using commonly available equipment, alongside extensive and systematic reference collections, as a method for differentiating between past tanning technologies. A brief outline is provided here.

Although this paper focuses on three of the following six processing methods, secure identifications rest on knowing the characteristics of each. This methodology employs observations of an extensive sample reference collection, both macroscopic and microscopic, to produce a database of defining characteristics for six tannage types or subtypes: rawhide, fat emulsion processed (wet scrape), fat emulsion processed (dry scrape), urine tan/treatment, vegetable tan, and alum taw.

The primary collection contains 22 key species identified as economically important from Europe and North America. These include bighorn sheep (*Ovis canadensis*), bison (*Bison bison*), black bear (*Ursus americanus*), coyote (*Canis latrans*), elk (*Cervus canadensis*), mule deer (*Odocoileus hemionus*), pronghorn antelope (*Antilocapra americana*), Exmoor pony (*Equus ferus caballus*), fallow deer (*Dama dama*), Galloway cow (*Bos taurus*), roe deer (*Capreolus capreolus*), red deer (*Cervus elaphus*), Soay sheep (*Ovis aries*), Toggenburg goat (*Capra aegagrus hircus*), wild boar (*Sus scrofa*), badger (*Taxidea taxus*), beaver (*Castor Canadensis*), dog (*Canis lupus familiaris*), red fox (*Vulpes vulpes*), moose (*Alces alces*), rabbit (*Sylvilagus* sp.), and reindeer (*Rangifer tarandus*).

A secondary collection of clothing and utilitarian items made from traditionally processed skins was included to add ›in-life‹ use traces to the database. These behavioural characteristics are included as part of the methodology because they are specific to the tannage type. Because they are set in place during the object's use life, post-depositional changes, such as over-tannage from bog interment, affect this set of characteristics very little. For a full description of the geographical, chronological, and technological parameters of this methodology, see Emmerich Kamper 2020, 18.

The method was tested against 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 detail into aspects 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 the conservation, curation or analysis of archaeological or world culture collections of skin objects. It provides a consolidated source of information for artisans working with traditional tanning or re-enactors interested in the history and science of skin products.

Processing Methods

Most skin processing methods break down into three stages: subtractive, additive, and mechanical. The variations and terminology within these are described below with the help of Fig. 1, showing the skin structures and dermal layers, and Tab. 2, 3 and 4, which outline the subtractive, additive, and mechanical stages of skin processing. The subtractive stage removes unwanted components such as the subcutaneous tissue, hair, or the grain layer. These are often referred to as pre-processes or pre-tanning processes. The additive stage introduces reactive compounds (i.e. the fat emulsion or vegetable tannins). This is the stage where most chemical processes happen and is the stage most often referred to as ›tanning‹. The mechanical stage involves repeatedly moving the fibres of the dermis past each other so that they do not set or harden as the skin dries or in order to loosen a fibre structure after it has dried.

The epidermis is the outermost layer of the skin (Fig. 1). This thin but complex layer is broken down bacterially or chemically and is not present on de-haired skins except as an anomaly. The underlying papillary dermis is composed primarily of connective tissue, specifically collagen fibres, made of the same structural proteins (collagen type 1) that are the main component of the rest of the dermis. This layer is also referred to as the grain layer and is composed of very fine, densely packed fibres. The upper layer of the papillary dermis gives the grain (outer) surface its smooth, reflective quality, whereas its removal leaves a double-sided ›suede‹ finish. The underlying dermal layer is the reticular dermis and is composed of thicker and more loosely interwoven dermal fibres. There is a transition zone between the deeper reticular dermal layer and the papillary layer. When the grain layer is removed, it is at this transition zone. Removal of the grain layer is always a mechanical rather than chemical process.

Vegetable tan, in all its variation, rarely, if ever, has the grain layer removed. Emulsion-processed leather most often has the grain layer removed. However, there are examples of emulsion-processed leather both in archaeological contexts and in modern indigenous communities where the grain layer is left intact. Many arctic communities do not remove the grain before tanning sea mammal skins (e.g. Issenman 2011; Wilder 1976; Oakes/Riewe 1995). The Saami regularly produce grain-on emulsion processed reindeer skins (Rahme 1996; Klokernes/Kunstakademi 2007), and some artefacts observed during the author's fieldwork in Europe and North America were grain-on emulsion-processed leather.

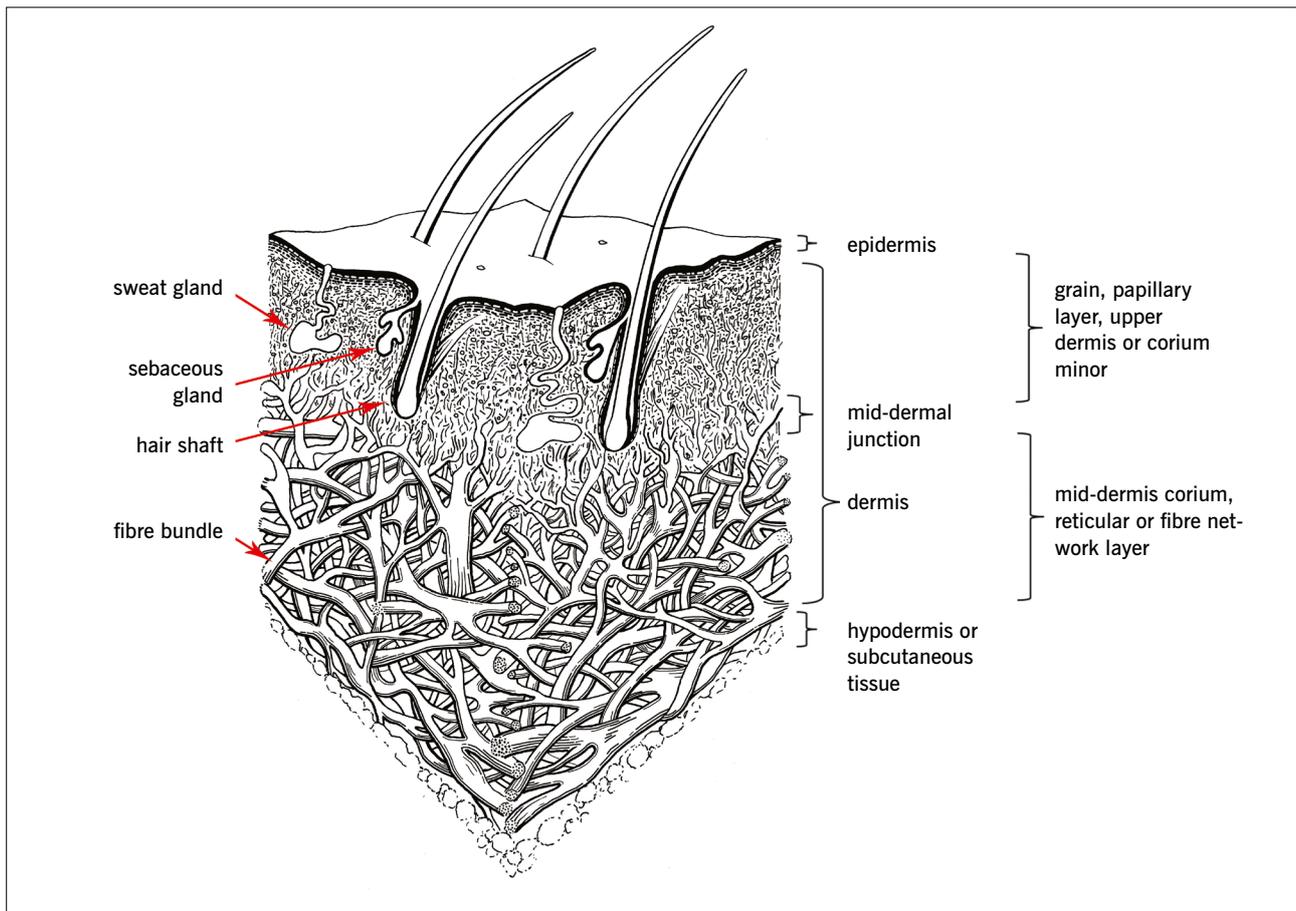


Fig. 1 Cross section of generic mammal skin showing dermal morphology.

Abb. 1 Querschnitt durch die generische Haut eines Säugetiers mit Darstellung der dermalen Morphologie.

Subtractive Stage

Several general reductive treatments are performed on a skin prior to the more specific additive treatments that characterise each processing technology. This subtractive stage is defined by something being taken away from the skin: removing subcutaneous tissue (de-fleshing), hair, epidermis, grain layer (papillary dermis), and the ground substance are all subtractive steps. How and if some or all these steps are undertaken is influenced by environment, location, time-period, and cultural traditions (Tab. 2).

Additive Stage

The additive stage of skin processing has perhaps the most variation of any tanning stage. This stage is defined by the addition of reactive substances that interact with the structural proteins of the dermis to change its visual and behavioural characteristics. The reactive agents are most often introduced to the dermal tissue in one of two ways: by rubbing moist mixtures into dry, semi-dry or wet skins or immersing the skin into a solution containing the reactive agents. Water is necessary as a transportation aide for the reactive substances for all tannage technologies (Tab. 3).

Mechanical Stage

The mechanical stage of skin processing is concerned with manipulating the fibres of the dermis so that they retain a level of flexibility as the skin dries or regain some flexibility if this step is done after the skin has dried. Softening the skin is achieved by manipulation of the fibre structure in all directions until the dermis loses all moisture. Dried skins are commonly remoistened before undergoing this process (Tab. 4).

The species for the reference collection had to cover a global reach, but more importantly, the collection had to include the range of species available in different periods and utilised for various products. Species differ in their suitability for the three tannage technologies known to be available in prehistory. Three characteristics need to be considered for the available species, which are outlined in their potential for clothing.

The first is the choice to keep or remove the hair/fur. The thermal qualities of fur made some species more attractive than others. Water mammals, in particular, such as beaver and otter with their dense fur (i.e. numerous hairs per square centimetre) are highly suitable to providing warmth. Some furs shed water more easily than others. Both warmth and water shedding could be reasons for the selection of certain species to use for clothing. The hair of most deer families

Tab. 2 Subtractive processes: removal of unwanted components in processed skin.

Tab. 2 Subtraktive Prozesse: Entfernung von unerwünschten Bestandteilen der verarbeiteten Haut.

	Subtractive stage
De-fleshing	<p>The mechanical removal the subcutaneous tissue made up of flesh, fat and connective tissue is a ubiquitous step in all skin processing, including rawhide. These tissues rot rapidly degrade the dermal tissue beyond use. Can be done with the skin in a dry or wet state.</p>
De-hairing and de-graining	<p>General overview: The removal of the hair/fur while leaving the grain layer (papillary dermis intact) or the removal of the grain layer and the hair/fur. Removing the fur or hair from some species, but not from others is based on the intended final use for the skin. Removal of the grain layer is common for emulsion processed skins as it facilitates the penetration of the emulsion. This step can be omitted if the intended product requires a more water-resistant surface and does not require the same amount of drape (flexibility and stretch) as can be achieved by its removal. This is commonly done in one of three ways.</p> <p>1-Mechanical:</p> <ul style="list-style-type: none"> • Hair can be shaved off with a sharp stone or metal tool with the skin in a dry state, while leaving the grain layer intact. • The grain layer and hair can be simultaneously removed using the same method. • The grain layer and hair can be removed from a wet skin by laying the skin over a tanning beam and scraping it with a tool with a distinct but dull edge. <p>2-Bacterial:</p> <ul style="list-style-type: none"> • Allowing skin to rot in a controlled manner breaks down the keratin-rich epidermal layer and loosens the hair root. Commonly referred to as ›sweating‹, the hair can then be pulled out or pushed off the skin, leaving the grain layer intact. • If the grain layer is to be removed, it must be scraped off mechanically as stated above. <p>3-Chemical:</p> <ul style="list-style-type: none"> • A more easily controlled method of hair removal uses alkaline pH to slip the hair. An alkaline solution breaks down the epidermal keratinocyte layers and allows the hair to loosen in the follicle. • Potassium hydroxide, the alkaline component in wood ash, was a readily available material for the time period and well documented in indigenous cultures as a de-hairing and degreasing agent. • If the grain layer is to be removed, it must be scraped off mechanically as stated above.
Ground substance removal	<p>Ground substance is the extracellular matrix that exists between the collagen fibres and other structural proteins. Most of which is removed in all skin processing technologies, except for in rawhide. The less ground substance present, the softer and more flexible the product. A desirable trait for most clothing.</p> <p>Ground substance can be removed by:</p> <ul style="list-style-type: none"> • Mechanically via intensive scraping and washing. • Bacterially via enzymatic action. • Chemically via changes in the solubility of the proteins.

breaks off easily, making it less suitable as a hair-on-skin than species with a solid hair shaft. In contrast, the leather made from de-haired deer skin is one of the most versatile for clothing manufacture. Reindeer skins with the hair on (intended for clothing, rather than any other purpose) are best harvested in the late summer or early autumn, as the winter coat is too warm and the hair is too brittle to produce optimum garments.

The thickness and the looseness of the fibre structure of the dermis are a consideration both for the tanning technology employed and the type of clothing that could be produced from it. Thick skins with a dense, tight fibre structure, such as cow, are better suited to vegetable tan or rawhide, whereas a thick skin with a loose fibre structure, such as bison or moose, can be processed using emulsions to provide

	Additive stage
Rawhide	No reactive agents are used for preparing rawhide.
Emulsion processed leather	brain, egg yolk, fish oil, marine mammal fat, milk, fish roe <ul style="list-style-type: none"> • liver, spinal fluid, tallow • used in addition to the more common agents
Vegetable tanned leather	A wide range of species containing tannins exist in each environment. Use is based on availability and characteristic preference. Some common species are: <ul style="list-style-type: none"> • bark/wood: oak, chestnut, spruce, larch, birch, acacia, quebracho • roots: dock, tormentil, rhubarb • fruits/rinds/oods: acorns, acacia, tara, mimosa, coffee, galls • leaves: sumac, olive, acacia
Smoke	Smoke is antimicrobial, slows bacterial, fungal decay and deters insect predation of the finished product. Only emulsion processed skin and occasionally rawhide is smoked. Skins processed with oils/fat emulsions, are more versatile after smoking in that they better withstand repeated wet and dry cycles. The temperature of the smoke is unimportant if the skin is exposed for a long enough span of time. Some common smoking methods are: <ul style="list-style-type: none"> • Hanging in a smoke house or the rafters of a shelter. • Being sewing it into an open-ended bag and placed over a stove pipe or hole in the ground.

Tab. 3 Additive processes: common reactive agents for prehistoric processed skin.

Tab. 3 Additive Prozesse: gängige reaktive Substanzen für prähistorische verarbeitete Haut.

a soft, lightweight product. Some smaller animals have very thin skin, which, while able to be processed using any of the available technologies, can be fragile. Small skins from birds and hare may be used where larger animals are less available, or where their thinness is an advantage, such as for children's clothing. At the other end of the scale, larger animals, such as bison, have areas of very thick skin that are commonly cut out or used for items that must withstand substantial mechanical stress, such as shoes. However, for robes or tent skins, thick areas are thinned during the subtractive stage by scraping away layers of tissue as a way of reducing weight.

For clothing, the animal's overall size can also influence its use. Animals in the deer size-range strike a good balance between size in square metres and thickness of the dermal tissue. Smaller animals require less effort to tan, but more time is spent sewing, and more complex patterning is necessary. Environmental conditions dramatically influence both the species used and the tannage technology chosen. In dry conditions, emulsion-processed skin and rawhide have good longevity. The traits of emulsion-processed leather work well for clothing as the skins range from flexible to very soft and are lightweight, breathable, resistant to acidic conditions (sweat), and can be easily sewn and washed. In contrast, skins processed using vegetable tannins weigh more, are less breathable, and must be re-oiled after wash-

ing. However, they can be oiled or waxed on the grain side surface to repel water, have a higher heat resistance and are non-putrescible in situations where the skin stays wet for long periods of time. Behavioural characteristics of the different tannage technologies and their influence on clothing design and choice will be further expanded in future publications.

Conclusion

We have provided a brief overview of the skin processing technologies for the period covered by this volume. The steps have been outlined as a series of choices, and we have endeavoured to show how these selections have carried through into the characteristics of the clothing produced from them. The availability of the various animal species has implications for insulation, flexibility, pattern layout, and stitching time. Here, we have shown that when considering the choices made by prehistoric groups, there is a complex interplay between both the environment as the climate in which humans need to survive and the environment as the opportunity to acquire those faunal resources needed as raw materials.

Many of the characteristics are determined by the tanning technologies chosen and can provide very different

Tab. 4 Mechanical processes: common methods of imparting flexibility to processed skin.

Tab. 4 Mechanische Prozesse: gängige Methoden, um verarbeiteter Haut Flexibilität zu verleihen.

	Mechanical stage
Hand working	Pulling or pushing skins in all directions using the tanner's feet, knees, and hands. Commonly used for thin or loose fibred skins.
Staking	Pulling or pushing skins over a solid post with a blunt U-shaped end or pulling them through a cable fixed at both the top and bottom, or a similarly through a fixed bone or wooden D shaped tool secured to a solid object.
Frame working	Lacing a skin into a wooden frame or hoop. The fibre structure of the skin is moved by pushing a tool with a blunt U-shaped end into the skin and dragging it in various directions to stretch and move the fibre network. Often used for thick, hair on or very large skins. Also used to flatten rawhide as it dries.

products. Although we have more tanning technologies at our disposal today, even the early tanning technologies provide an extensive range of different qualities which are entirely dependent on people's choices. Understanding the

practical parameters allows for a much greater appreciation of the possibilities for clothing in these early periods. Leather is not simply a material, but a rich sphere of knowledge allowing us to appreciate how early societies thrived.

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Source of figures

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