

**ESF Exploratory Workshop on
Archaeology of Sheep Domestication:
New Approaches**

London (UK), 16-19 May 2010

**Convened by:
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SCIENTIFIC REPORT

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1. Executive summary

Workshop background

Sheep is one of the earliest domesticated animals that has contributed to the subsistence of human populations since at least the 7th millennium BC, in particular as the source of wool, one of the most important textile fibres. Wool textiles recovered from archaeological contexts provide a unique source of information about the domestication, use and economy of sheep, especially in combination with other sources of evidence, such as animal bone assemblages, ancient written sources and iconography. The workshop reviewed the possibilities and limitations of developing new methods for the analysis of ancient wool fibre and other materials, thereby establishing a new direction in textile/fibre and sheep domestication research and demonstrating the importance of natural science methods in archaeology. The exploratory workshop promoted interdisciplinary approach as it gathered specialists in archaeology, wool fibre, linguistics, ancient DNA, isotopic tracing, zooarchaeology and other fields to explore the new research directions in investigating sheep domestication and development of wool fibre, and to establish a cross-disciplinary network for a possible future large-scale project.

Workshop aims

Although sheep is one of the earliest animals domesticated by humans, yet, paradoxically, it have not been the focus of investigation on the same level as some other domesticates, such as pig, cattle, horse or chicken. Nevertheless, numerous scholars and research groups are currently engaged in various projects that approach the questions related to sheep domestication from various methodological perspectives. In order for the field to develop in the most constructive way, a dialogue is necessary between the different disciplines, scholars and projects. The aim of this exploratory workshop was to promote such dialogue and an interdisciplinary approach to the investigations of sheep domestication. A further aim was to promote the use of natural sciences in archaeology. The workshop focused on reviewing the developing new methods for the analysis of ancient fibre, thereby establishing a new direction in textile research and demonstrating the importance of natural science methods in archaeology. Developing the methodology has further potential for a large scale project on a European scale which will explore the historical development of ancient sheep breeds and their movements in prehistory. More specific aims were:

1. To evaluate the old and to discuss new fibre analytical methods and ways of interpreting obtained data.
2. To demonstrate the potential of archaeological fibre for the investigation of ancient economy, technology and agriculture and to integrate fibre studies into interdisciplinary research of broader archaeological interest.
3. To establish a cross-disciplinary network of specialists for a future large-scale project.

Workshop organisation

The workshop was convened by Margarita Gleba (Institute of Archaeology, University College London, UK) and co-convened by Caroline Solazzo (University of York, UK), both Marie Curie Fellows at their respective institutions and in the early stages of their careers. The workshop was hosted by the Institute of Archaeology, University College London on 17-18 May 2010. The participants were staying at the Tavistock Hotel, which was located a 2 minute walking distance from the workshop venue. Participants arrived on the 16 May and,

with the exception of the two who had to depart early due to British Air strike and volcanic ash cancellations, departed on the 19 May. A total of 24 participants from 10 ESF and 3 non-ESF countries attended the workshop. One of the participants included in the final programme was unable to attend due to last-minute family emergency. Another participant, while unable to attend due to travel complications created by the volcanic ash, sent his paper and presentation, which was delivered by a collaborator.

Participants were invited to send extended abstracts of their papers two weeks before the workshop. Given the highly interdisciplinary nature of the workshop, this provided an opportunity for the participants to familiarise themselves with the topics/problems to be addressed by the fellow participants and facilitated the discussions following each paper and session. The workshop consisted of 6 sessions each focusing on specific type of evidence (textiles, animal bones, literary sources) and various methodological approaches (microscopy, isotopic tracing, molecular studies). Each session included 3-4 papers of about 20 minutes. On May 17, following the welcome by the director of the UCL Institute of Archaeology and the ESF representative and the introduction by the organizers, 11 papers were given. On May 18, 10 papers were given. All communications were in English. Although originally it was intended to hold a discussion following all papers in each session, it soon became clear that discussion of each paper after it was given was preferred by everyone. Since ample time was allowed for discussions in the programme and all the participants generally adhered to time allotted, the questions and discussions were not limited. The workshop ended with an overall discussion session on the state of the art in the field, follow-up activities such as a joint review article and prospects of future collaborations and further meetings.

The workshop was held in a relatively small seminar room which provided for an intimate and congenial atmosphere. The coffee breaks and lunches were organised in the adjacent staff common room, which provided a more relaxed setting for the continuation of discussions between the sessions and for interactions of scholars from very different fields. Lunches and refreshments for the breaks were provided by the UCL catering. The organised dinners on the evenings of workshop days (held in a local Greek and Indian restaurants on Monday and Tuesday respectively) also greatly contributed to additional interaction.

The general atmosphere of the meeting was very enthusiastic and congenial. The participants arrived ready to learn and many of them commented in their communications after the workshop that they took away a lot of very useful information and most importantly new contacts that will be extremely useful in the future for sharing data. The discussions proved the most important component of the workshop for developing future collaborative research; they extended ideas and concepts more fully, offered opportunities for participants to combine their fields of expertise, and allowed all to reassess their own knowledge with fresh perspectives and a deeper understanding of other evidence and methodological approaches.

Workshop Outcome

During the workshop, the participants and the convenors mutually informed each other about the on-going and forthcoming research projects related to archaeology of wool and sheep domestication. The participants were invited to join the projects and to communicate with other scholars in their home countries about these on-going or future research projects related to textiles.

The convenors and the participants agreed to publish State-of-the-art review in Journal of Archaeological Research or Journal of Archaeological Method and Theory (both top-rated and highly cited publications), as soon as possible. It was agreed to set the submission deadline for manuscripts to 15 October, 2010.

Margarita Gleba will be the first author and the coordinator of the article.

All participants also agreed about the necessity of holding further meetings and involving other colleagues working in the field, as well as specialists in modern animal husbandry. To that end Margarita Gleba and some of the other participants will apply for funding to hold further meetings in over the course of the next 5 years (ESF Research Networking Programme being one possible source of future funding). It is hoped that these future meetings will consolidate the network and eventually lead to a larger scale project.

2. Scientific content of the event

Stephen Shennan (Director of Institute of Archaeology, University College London, UK) welcomed the workshop participants and provided an overview of some recent work on the beginnings of domestication in Europe and Asia, setting a backdrop for the workshop. Sheep domestication took place probably at an early date before ~8500 cal BC in the Upper and Middle Euphrates Valley. However, after ~7500 cal BC the amount of sites with domestic sheep remains increases considerably, and extends far away from this area to the Mediterranean and the Southern Levant where a sudden start is observed. Sheep remains become dominant after the domestic goat in many bone assemblages.

T. Hevin Jones (ESF Standing Committee for Life, Earth and Environmental Sciences, LESO) presented the European Science Foundation and its various programmes.

This was followed with an introduction by the convenors, **Margarita Gleba** (Institute of Archaeology, University College London, UK) and **Caroline Solazzo** (University of York, UK), who gave a short state of the arts summary for the field of sheep domestication and wool studies, and the various methods available or being developed for approaching these issues. The convenors also provided practical information regarding the organisation of lunches, breaks and dinners etc.

After these introductions, the workshop commenced with **Session 1**, which included four papers dealing with the archaeology of wool textiles. Knowledge of textile history is key to our understanding of a multitude of human issues as textiles represent one of the earliest human technologies, certainly older than metallurgy, and they have been a fundamental part of subsistence, economy, and exchange. Textiles thus have an enormous potential in archaeological research, being able to tell about social, chronological, and cultural aspects of past societies. Wool textiles, moreover, represent a unique material for the investigation of sheep domestication. The first speaker, archaeologist and biologist **Margarita Gleba** (Institute of Archaeology, University College London, UK) provided an overview of the current state of knowledge about ancient wool textiles, including properties and use of wool fibre, basics of sheep husbandry, the earliest wool textile finds and the special conditions of wool

textile preservation, as well as the methodology of fibre quality analysis established by Michael Ryder in 1960s, on the basis of which the current classification of ancient sheep fleeces is based.

The next speaker, textile archaeologist and conservator **Irene Good** (Harvard University, Boston, USA), explored the questions of what triggered wool's development, how, when and why did it develop, whether it was an indirect result of dairying, and whether wool emerged independently in different regions. The paper also highlighted detailed research on fibre analysis of the earliest archaeological wool textiles found to date, which come from a late Chalcolithic-Early Bronze Age (3100-1800 BC) site Shahr-i Sokhta in the Hilmand region of eastern Iran. Ninety-six textile samples from the site are composed of animal fiber. Through careful examination and comparison of sheep wool fibre samples several significant features can be discerned about the sheep breeds utilized for their fibre at the site, which are consistent with a fleece transitional between the ancestral coat and the hairy medium, according to the work of Ryder.

Ryder's model provides an invaluable foundation for fibre studies and demonstrates a strong link between fibre and textile. However, biological variations of fibre composition and the transformations that take place between raw wool and finished textile must be taken into account. A fleece of a primitive sheep may contain several qualities of wool. The composition of a fleece also varies between different animals of the same breed and further depends on the sex, age, and physical state of the animal. Fibre in a textile, moreover, is a product of numerous processes: breeding, selection, processing, and finishing. This was aptly demonstrated in a paper by **Linda Olofsson** (Trelleborg Museum, Trelleborg, Sweden), who in addition to being an archeologist is trained in traditional textile crafts techniques. She provided a step-by-step review of all processes that take place between removing the fleece from the sheep and creating a finished textile, based on traditional textile crafts and experimental archaeology and with particular emphasis on the impact of wool selection and methods of preparation. In the break following the session, the participants had an opportunity to handle tools and half-finished products, brought by Linda for demonstration. The session ended with a paper by archaeologist **Carol Christiansen** (Shetland Museum and Archives, UK), who further underlined the problems inherent in Ryder's system of fleece classification, basing her conclusions on tests and experiments designed to obtain a specific wool quality, which showed that same results can be achieved through careful processing of very different fleeces. She concluded that it would seem misleading, or even impossible, to identify fleece types and sheep breeds based on fibre diameter measurements. The session ended with the discussion of the fact that clearly other methods are needed to tackle the issue of sheep domestication and early fleece identification besides fibre measurements alone.

After the lunch break, **Session 2** discussed another important corpus of evidence traditionally used in domestication studies, zooarchaeological remains and ancient written sources. Zooarchaeologist **Barbara Wilkens** (University of Sassari, Sassari, Italy) gave an overview of sheep domestication evidence in Italy and Sardinia based on established methodology of morphological examination of animal bones. She emphasised that it remains impossible to differentiate amongst large part of bones between the genus *Ovis* (Sheep) and *Capra* (Goat). Furthermore, it is necessary to keep in mind the possibility that part of the remains could be from sheep or goat who have returned to the wild. Thus, the mouflon, derived in ancient times from domesticated sheep, is present today only on a few

Mediterranean islands, but it is probable that in the past small groups that formed and escaped from the control of man might have also been present in other areas. The issue of horned versus polled sheep was discussed since it appears the trait is variable even within the same breed. John McEwan noted that genetic markers for hornlessness have already been identified within Sheep Genome project and they may be used in the future aDNA investigations of ancient sheep bones to resolve the question.

Zooarchaeologist **Michael McKinnon** (University of Winnipeg, Winnipeg, Canada) considered a much later, Roman period in the Apennine peninsula, which represents one important temporal period when new varieties of sheep developed. Human choice of specific physical characteristics to promote and express within sheep, and the geographic and cultural manipulation of their breeding, resulted in phenotypic and genetic separation of taxa. McKinnon integrated three important data sets – zooarchaeological, ancient textual and iconographic sources – to gain information about the appearance of different breeds during Roman antiquity, which allows us to track their spread, trade and manipulation across time. The paper focused on tracing the patterns of sheep breed development in Roman Italy, the core of the Roman Empire, before outlining examples of breed development in the Roman Mediterranean provinces. Size and shape variation were used, as revealed from zooarchaeological metric data, to assess regional and temporal variation in sheep varieties. These data were compared to the descriptions of, and references to, sheep breeds, as found in the ancient Greek and Latin textual sources, as well as the visual images of sheep varieties as revealed in ancient art, many of which describe or show variation in wool colour and texture. This integrative approach, combining bones, texts, and art, provides a more holistic picture of sheep breed development in Roman times.

The following two papers in this session dealt exclusively with written sources, specifically some of the earliest written documentation in existence that provides invaluable information on early human sheep husbandry practices. Historian **Françoise Rougemont** (CNRS, Paris, France) gave an overview of data on sheep rearing and wool production in the Linear B tablets, the administrative records of Late Bronze Age Greece (1600-1200 BC), and problems associated with these data. One of the major problems is that practically no information exists regarding the appearance of the sheep and the existence of different sheep varieties. The iconographic evidence is too limited and biased to provide much help with answering these questions. It is where bone and genetic data may be of help in the future.

More detailed information comes from even earlier, 3rd millennium BC Sumerian administrative records of Mesopotamia. Linguist and historian **Marek Stępień** (University of Warsaw, Warsaw, Poland) gave a summary of Sumerian terminology of sheep and organisation of animal husbandry from Ur III period. Here, specific geographical and descriptive terms are given, indicating both the length and colour of fleeces. Most importantly, references to shearing exist, suggesting that already in this early period varieties of sheep existed which did not moult and required the fleeces to be removed artificially. John McEwan noted that at the moment no genetic markers for moulting have been identified in sheep.

The three papers in **Session 3** focused on the microscopic aspects of wool and problems inherent in archaeological fibres, which must be taken into account before undertaking any kind of more complex analytical approach to the material. Archaeological scientist **Andrew S. Wilson** (University of Bradford, Bradford, UK) gave an overview of hair histology and the

factors, hormonal and environmental, affecting hair follicle differentiation and hair growth. Selective breeding in sheep has affected the wool by replacing kemp with hair, creating a more uniform fleece, narrowing the hair diameter and has favored natural shedding. He spoke about the importance of understanding hair sample condition in archaeological and forensic investigation and showed how microbial degradation (such as fungal tunneling) affect the different layers of the hair shaft with selective destruction of the structures. He highlighted the need for a detailed knowledge of the sequence of degradation in samples that have been either buried or left exposed at the ground surface.

Textile archaeologist **Antoinette Rast-Eicher** (Archeotex, Ennenda, Switzerland) gave an overview of methods, results and limits of Scanning Electron Microscopy. The preservation of archaeological textiles determines the method of fibre analysis and SEM has become one of the most important techniques in fibre analysis for archaeological textiles. It is particularly useful for the investigation of metal-replaced wool fibres, which survive only as holes with the negative imprints of the surface scale pattern on the inner side of a cast created by metal salts. Investigation of thousands of such metal-replaced samples from various periods found in Switzerland and Central Europe using SEM has permitted a statistically significant and largest to date study of ancient wool fibre, which demonstrated changes through time in fibre quality, as well as identification of some processing techniques. Rast-Eicher also commented on the need to revise Michael Ryder's system of fleece classification and proposed an alternative method, which she has developed on the Swiss material.

Physicist **Bodil Holst** (University of Bergen, Bergen, Norway) presented novel microscopy and diffraction techniques, which have recently been applied in the identification of ancient textile fibres, in particular environmental SEM, which is a non-destructive method, X-Ray Diffraction and Atomic Resolution Transmission Electron Microscopy, which allows identification of individual molecules and, in combination with elemental analysis, identification of dyes. These techniques are of great importance when the fibre is so degraded that traditional methods are useless. Holst offered the participants to collaborate in applying these methods (some of which are still being developed) to ancient samples of particularly difficult nature.

The second day of the workshop was devoted to new and developing scientific methods of investigation that are or can be applied to archaeological material such as textiles or animal bones to study sheep domestication. **Session 4** was dedicated to isotopic tracing. The first two papers focused on the application of isotopic methods to sheep bones. Zooarchaeologist **Carlos Tornero** (Universitat Autònoma de Barcelona, Barcelona, Spain) recounted the latest advances with isotopes on sheep bones and teeth from the early stages of domestication, emphasising the potential of stable isotope analyses as a methodological approach in zooarchaeology capable of bringing an important contribution to the study of herding strategies and changes due to animal domestication.

The issue was picked up by biochemist **David Meiggs** (University of Wisconsin, Madison, USA) who spoke about isotope variation in prehistoric skeletal remains and their implications for sheep domestication, in particular distinguishing signatures of human control of animals from those arising from natural variation. Increasingly, zooarchaeologists have argued that the initial phases of animal domestication in southwest Asia are not observable morphologically but may be visible, for example, in reconstructed sex-based culling practices. Isotopic analysis of ovicaprine remains have shown that recoverable biogenic signatures provide useful evidence of geographic, seasonal, and dietary variability which

may shed further light on human animal exploitation and incipient herd management practices. Moreover, because they reflect individually-based time scales, they have the potential to document the character of the earliest phases in animal husbandry. A major question remaining in these approaches, though, is whether and how we can clearly distinguish between human intervention and natural variation in these early periods. At present we should be circumspect about interpreting either carbon or oxygen isotope signatures in stark environmental terms.

The following two papers presented new and ongoing research on developing provenance tracing methodologies based on various isotopes. Origin is one of the hardest pieces of information to obtain about any archaeological object in absolute terms. Geochemist and archaeologist **Karin Margarita Frei** (University of Copenhagen, Copenhagen, Denmark) presented a new and very important method she has developed by applying strontium isotope analyses to modern sheep hair as a basis for its potential use as a provenance tracer for ancient wool textiles. $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of decontaminated sheep hair agree well with the compositions of biologically available strontium fractions from the respective feeding ground soils, a translatable requirement for any potentially successful provenance tracing applied to wool textiles. Application of this new method to archaeological samples from Denmark has already yielded unexpected results, indicating a non-local origin of wool for textiles previously thought to be of local origin.

Isabella von Holstein (University of York, York, UK) presented an alternative and/or complementary method to trace provenance of wool fibre, based on multiple light stable isotope approach. Her project aims to establish whether combined carbon, nitrogen, sulfur, oxygen and hydrogen stable isotope value ($\delta^{13}\text{C}$, $\delta^{15}\text{N}$, $\delta^{34}\text{S}$, $\delta^2\text{H}$ and $\delta^{18}\text{O}$, respectively) analysis can be applied to samples of sheep wool and bone from archaeological sites in North West Europe from the period AD 600-1500, in order to explore the development, extent and nature of trade flows in wool textiles and raw wool.

During discussion it was agreed that strontium and multiple light isotope systems should be combined in future studies to get the maximum information about the provenance and strengthen the conclusions in cases where neither method by itself provides conclusive evidence.

The last two sessions of the workshop focused on proteomics and genetics (**Session 5**) and genetics and genomics (**Session 6**).

Biochemist and archaeologist **Caroline Solazzo** (University of York, York, UK) presented a project which aims to trace ancient sheep breeds using the wool proteome. The wool proteome is composed of proteins from the keratin family and keratin associated proteins KAPs. It is suspected that variations in the distribution of the proteins can be linked to quality traits in wool. The THREADs project (Textile and Hair proteomics: Re-examination of European wool from Archaeological Deposits) between AgResearch and BioArCh aims to create proteome maps for selected breeds, highlighting the differentiation in the protein composition. Preliminary results on Soay, North Ronaldsay, Icelandic and Shetland sheep have shown significant differences in the distribution and expression of proteins when compared to Merino and Mouflon. The results will be linked to fibre types that will be compared at a later stage to historically documented fibre types and archaeological textiles from major textile centres and regional markets.

Miika Tapio (MTT Agrifood Research Finland, Finland) discussed modern indigenous sheep breeds and how they can help in studies of sheep domestication. The general marker

diversity patterns for indigenous sheep seem to agree with expectations based on archaeological evidence, which is that high genetic diversity decreases to the west of Europe as compared to the highest diversity present in the Near East. However, there are several areas where genetic studies on contemporary breeds could offer more insights. Among the traditional types of studies, more details on spread of maternal lineages would be expected if full mitochondrial genomes are sequenced. Even more interesting development is the emergence of genomic approaches. The genomic analysis technology is making tracing genomic segments possible. In addition to standard population genetic approaches, combining this type of data with data on external characteristics might prove very informative, and in the very best case offer genetic predictors for inferring details of the sheep type for ancient samples. In this the primitive indigenous sheep and their crossbreeds are likely to be highly informative, although it is important to remember that no modern population is expected to be genetically identical to ancient sheep.

Molecular biologist **Massimo Palmarini** (University of Glasgow, Glasgow, UK) discussed how by using endogenous retroviruses as genetic markers, his team found that sheep differentiated on the basis of their “retrotype” and morphological traits dispersed across Eurasia and Africa via separate migratory episodes. Relicts of the first migrations include the Mouflon, as well as breeds previously recognized as “primitive” on the basis of their morphology, such as the Orkney, Soay, and the Nordic short-tailed sheep now confined to the periphery of northwest Europe. A later migratory episode, involving sheep with improved production traits, shaped the great majority of present-day breeds. The ability to differentiate genetically primitive sheep from more modern breeds provides valuable insights into the history of sheep domestication. The use of retroviruses as genetic markers may also be useful in studies of the relationships between ancient breeds.

aDNA specialist **Tom Gilbert** (Museum of Natural History, Copenhagen, Denmark) discussed DNA survival in modern and ancient wool, and implications for bioarchaeology (paper presented by Matthew Collins, University of York, York, UK). Over the past decade not only the survival of, but the recovery of PCR amplifiable DNA from ancient sources of hair shaft has been demonstrated. Although initially limited to reports of mitochondrial DNA (mtDNA), it rapidly became clear that nuclear DNA (nuDNA) could also be often retrieved, in particular following the development of PCR independent modern High-Throughput DNA Sequencing Platforms, which to some degree enable much shorter targets to be sequenced. As a result of a particular advantage of hair over many other ancient tissues, that of limited source contamination, these latest techniques have recently helped ancient DNA research enter a new era, that of ancient genomics, culminating with the recent publication of the first ancient nuclear genome to be sequenced with high coverage. Given these results, and the power that ancient genetic studies might be able to offer the study of the domestication of sheep, one might expect that ancient wool samples will offer a valuable tool for future study. However, caution should be taken prior to undertaking such analyses, as the following problems have to be taken into account: shaft keratinisation process which results in poor DNA recovery, hair by hair and length variation, DNA damage that may occur during the wool treatment, post-modern DNA degradation in the time since an ancient wool sample was created, and the present. Recent pilot study conducted on a selection of modern wool samples (undyed and dyed) and ancient textile samples have yielded variable results. They show that no pattern can be seen by breed, hair colour or location on the body. But mordanting with metals has a major effect on the survival of aDNA, in comparison to dyeing

without the use of mordant which seem irrelevant. Burial conditions also have an effect on DNA preservation.

Biochemist and biologist **John McEwan** (AgResearch, Otago, New Zealand) gave an overview of the International Sheep Genomics Consortium Sheep Genome and HapMap Projects and what they mean for investigations of ancient wool and sheep domestication. Selection has been imposed on sheep populations since the domestication process commenced approximately 12,000 years ago. The result is a spectrum of phenotypically distinct breeds which display adaptation to different environments and the specialised production of meat, milk and fiber. In order to search for genetic signatures of selection, the ISGC assembled and genotyped over 3,400 sheep from 74 diverse breeds using the ovine SNP50 BeadChip. Initial testing of the SNP50 BeadChip revealed 91% of 59,454 loci formatted for analysis displayed assay signals following genotyping. Of these, 5,207 were removed using a series of quality control filters. Allele frequency data from the remaining 49,034 loci was used to search for signatures of selection using multiple methods. Clear signals, in the form of outlier SNP, were detected surrounding both the Myostatin and Horns (Ho) locus. Further, breeds were partitioned to capture extremes for a variety of traits including highly complex examples such as parasite resistance. Genomic regions were presented which appear to have undergone selection and which, in a number of cases, contain genes which are known to directly contribute to phenotypic variation. McEwan concluded that in order for the ancient sheep DNA studies to proceed, the key breeds still need (re)sequencing which requires better existing breed samples; the early period of domestication has to be examined and a database of ancient data created; quick tests need to be created for species, sex, horn presence, colour, fat tail presence and wool type.

The last paper by zooarchaeologist **Auli Tourunen** and aDNA specialist **Marianna Niemi** (MTT, Agrifood Research, Finland) presented an important integrative project currently taking place in Finland: The early history of sheep in Finland: combining zooarchaeology, historical sources and aDNA. The project combines various sources like zooarchaeology, historical written sources and aDNA-studies to form a more complete picture of the arrival and development of animal husbandry and sheep and cattle populations in Finland. It has been assumed that animal husbandry arrived to Finland during the late Stone Age with Corded Ware Culture; however no direct environmental evidence of this exists. During this project a number of late Stone Age, Bronze Age and Early Iron Age (ca. 3000 BC-AD 300) burnt animal bone samples will be analysed to examine the early adaptation and spreading of animal husbandry. A combination of zooarchaeological evidence with aDNA data will permit to examine the introduction of sheep breeding to Finland. The paper was a good demonstration of what can be achieved through a combination of interdisciplinary methods. The remaining part of the workshop was dedicated to general discussion of the topics covered by the various papers in the course of two days and future perspectives.

3. Assessment of the results, contribution to the future direction of the field, outcome

Results

Textile craft and agriculture are two of the most ancient human technologies, which throughout history played crucial role in world-wide socio-economic change. Textile production is tied to agriculture and animal husbandry through fibre, since the raw material, in our case sheep wool, is obtained from domesticated animals. Issues addressed during the

workshop through the investigation of archaeological fibre included ancient agriculture, husbandry, trade and economy, development of new strategies of fibre acquisition, diversification and spread of domesticated animal breeds. The workshop focused on reviewing the state-of-the-art on these questions and developing new strategies for the analysis of ancient fibre, thereby establishing a new direction in textile research and demonstrating the importance of natural science methods in archaeology.

The workshop had three objectives:

1. To evaluate the old and to discuss new fibre analytical methods and ways of interpreting obtained data.

Wool has been a major textile fibre since antiquity (Gleba). Much valuable research has been done on ancient sheep husbandry. Ancient written sources, in particular extensive archives from the ancient civilizations of Mesopotamia and Crete, but also later Greek and Roman literary evidence are being explored and provide us with detailed information of the most sophisticated sheep husbandry knowledge and organisation (Rougemont, Stępień).

Wool has also been studied through animal bone assemblages and transhumance patterns (Wilkens, McKinnon, Tornero, Meiggs). As early as the beginning of the 6th millennium BC, when the first evidence for farming in Europe appears, sheep are among the most important domestic animals. During the 3rd millennium BC, the mortality data of faunal samples indicate the increasing importance of animal secondary products, such as wool; although interpretation of these profiles remains controversial. By 1000 BC, generalized stock-keeping had been replaced by a more intensive fibre acquisition system, with stocks consisting mostly of sheep, and with a distinct emphasis on wool production. The study of zooarchaeological assemblages and transhumance patterns is essential for understanding the past strategies in fibre production by identifying sites and regions, which specialised in wool production.

Textile research has demonstrated that several distinct wool qualities were used in prehistoric times, some of them simultaneously already in the 4th millennium BCE (Good). This indicates that several varieties of sheep, each providing fibre of specific quality, were present during prehistory, thus demonstrating that prehistoric human deliberately selected for and exploited different breeds. Since 1960s, Michael Ryder established an evolutionary scheme for wool development based on fibre diameter measurements. Ryder's model, however, implies a direct link between fibre and textile but it does not take into account what happens between raw wool and finished textile. More recently, fibre in a textile has been seen as a product of numerous processes: breeding, selection, processing and finishing. The work in fibre analysis (Christiansen and Rast-Eicher) shows that the situation is even more complex since many different qualities of wool can be differentiated within the types defined by Ryder.

In order to understand the genetic nature of and the relationship between these breeds, textile fibre may be used as a source of genetic data. DNA has been used for some time in studies of the past and it is a rapidly developing research field with great potential. Genetic data from archaeological specimens provides an important new source of information for addressing questions in prehistory. Ancient DNA sequence analysis (Gilbert) can provide information on past genetic structure and diversity of animals, which can help to reveal the origin and history of domestic animals. Recent research has thrown considerable light on the history of domestic sheep, although few studies are based on ancient sheep specimens (Tourunen and Niemi). In animal genetic studies the material commonly used consists of

bones. Archaeological wool textiles constitute a hardly explored source of ancient sheep DNA, even though hair has been demonstrated to contain DNA. Techniques and methods are getting more refined allowing extraction of minute amounts of DNA, such as present in hair shaft. The recent sequencing and publication of the modern sheep genome (by the AgResearch team and other members of the International Sheep Genomics Consortium) will certainly facilitate the identification of genes and genetic changes, which are the result of selective breeding (McEwan, Palmarini, Tapio). However it is the proteome and not the genome that governs the quality of the wool. Proteomics attempts both qualitative and quantitative comparisons of the protein composition of the wool fibres themselves. Technology from modern wool proteomics can be used to analyse the proteome of ancient wools (Solazzo). Ancient wool proteomes can be used as baseline data for primitive wool, and samples of wool located throughout Europe in both space and time can be used to explore the changing properties of wool. While little work has been done to date in differentiating ancient sheep breeds archaeologically, some possibilities have been noted. Combination of protein and DNA studies with zooarchaeological investigations may provide a new avenue of investigation. In addition several new methods are currently being tested for their application on archaeological wool fibre. A range of light stable isotopes (D, C, N, O, S) are being used to provide geographic resolution of modern sheep in Europe (von Holstein), and although a number of these isotopes have been compromised by anthropogenic signals, it may be possible to use this map to help discriminate geographic location of wool. Greater progress has been made in the use of $^{86/87}\text{Sr}$ (Frei). Strontium isotope ratios reflect underlying geology, more specifically the transfer of bioavailable Sr with negligible fractionation into grazing plants and thence into wool. The $^{86/87}\text{Sr}$ of wool in a fabric will indicate the geology of the pastures and therefore provenance. This new methodology is a potential breakthrough that will help securing the origin of the fibres and address the questions of exchange and trade.

2. To demonstrate the potential of archaeological fibre for the investigation of ancient economy, technology and agriculture and to integrate fibre studies into interdisciplinary research of broader archaeological interest.

Ancient fibres have rarely been investigated in this context. The reason most often cited for the absence of studies on ancient fibres is their extremely poor preservation. However, while ancient raw fibres only rarely survive in the archaeological record, sufficient quantity of textile fragments made of these fibres from different periods and different geographical areas are preserved in either original organic or mineralised state and they represent a unique source of information about fibres.

The exploratory workshop promoted interdisciplinary approach and the use of natural sciences in archaeology. Systematic collection of data and specialised analysis of fibre samples obtained from archaeological textiles would form a platform of unprecedented quantity and quality for understanding issues of domestication and development of animal species that served as textile fibre sources. The application of new combination of cross-disciplinary methods of investigation, textile and fibre analysis, isotopic tracing and DNA analysis, and comparison of this data with other sources of information, such as zooarchaeological remains and contemporary literary and iconographic sources provides a never before explored venue of investigation (Gleba, Tourunen and Niemi). This exploratory workshop is a reflection of the current interest in the subject and of a need to share information in pursuit of complementary research fields.

3. To establish a cross-disciplinary network of specialists for a future large-scale project.

Developing the methodology has further potential for a large scale project on a European scale which will explore the historical development of ancient sheep breeds and their movements in prehistory. Modern techniques have been largely used in archaeological sciences for many years and are part of a fast-developing field. However, because of the nature of animal fibers, their fragility and the reluctance to destroy rare materials, textiles have not been studied for molecular studies extensively. In the recent years, technologies have improved so much that it is now possible to extract DNA from hair, or to minimise the sampling of textiles. Advances in modern technology and also in the sequencing of the sheep genome made it very timely to start large-scale studies of textiles. That point is recognized by the facts that the convenors both received a Marie Curie EU grant to start such studies. The workshop came at the very exciting period where such studies can be undertaken and the workshop served to promote new opportunities and certainly future collaborations. The existence of the EFS- Research Network Advances in Farm Animal Genomic Resources and its interest in archaeological genetics is a further proof of the timeliness of the focus on sheep domestication.

The topic of sheep domestication is vast and is only the first aspect of a larger project that includes the development of historical and modern breeds and crossbreeds, as well as the domestication of other wool-producing animals. It is difficult to restrict the study of textiles to the unique development of sheep wool, while other fibers have been used in parallel to sheep wool or even together. Those include the development of Cashmere and Mohair goats camelid fibers, as well as fibers from furs and more exotic animals such as yak, muskox, etc., and should be integrated in future projects as well.

Follow-up Activities

Publication

The convenors and the participants agreed to publish a state-of-the-art review in high-impact publications *Journal of Archaeological Research* or *Journal of Archaeological Method and Theory*, as soon as possible. It was agreed to set the submission deadline for manuscripts to 15 October, 2010. Margarita Gleba will be the first author and the coordinator of the article. The review will follow the arrangement of the workshop in 6 sections, which proved to show a good evolution in ideas and methodologies.

Further meetings

The workshop was successful in the first step to bring people and disciplines together. The connections established during the exploratory workshop need to be maintained regularly by future small and focused meetings and to hopefully lead to a large scale project where groups can meet again. All participants also agreed about the necessity of holding further meetings and involving other colleagues working in the field, as well as specialists in modern animal husbandry.

To that end Margarita Gleba and some of the participants will apply for funding to hold further meetings in over the course of the next 5 years. ESF Research Networking Programme is one funding possibility. The idea is to have 4 small scale workshops focusing on specific issues, followed by a larger general meeting, which will bring together the work and ideas presented during workshops. Each workshop will be hosted by a team from one of the participating countries. At the moment preliminary proposals have been given by Carol

Christiansen to organise a meeting in Shetland and the Finnish team to collaborate on another workshop to be held in Finland. It is hoped that these future meetings will consolidate the network and eventually lead to a larger scale project.

New projects and network opportunities

During the workshop, the participants and the organisers mutually informed each other about the following on-going and forthcoming research projects related to archaeology of wool and sheep domestication:

- **Margarita Gleba** presented a summary of Project *FIBRE (textile Fibre in Italy Before Roman Empire)*, which she is conducting with the support of the European Commission Marie Curie Intra-European Scholarship at the UCL Institute of Archaeology. The project aims to use archaeological textiles of a specific geographical area – the Apennine peninsula (Italy) – to deepen our understanding of the development of textile fibres in general and sheep domestication in particular. Comparison of the results obtained through fibre, strontium and aDNA analysis of samples of selected archaeological textiles from various Italian sites dated from prehistory to the Roman period with information available from zooarchaeological material, as well as literary and iconographic sources.
- **Irene Good** reported on the forthcoming project *Bio-Cultural Dynamics of Secondary Products Revolution*, which will look at the domestication of sheep in the world through zooarchaeology, genetics, proteomics and other methods.
- **Caroline Solazzo** (University of York, York, UK) presented the *THREADs* project (*Textile and Hair proteomics: Re-examination of European wool from Archaeological Deposits*). This project aims at looking at the development of wool and sheep breeds in Europe before the advent of industrialization and scientific sheep breeding, by using proteomics to look at the protein composition of wool and determine some quality traits. The project also aims at evaluating protein damage at different stages of the fiber's life: processing, dyeing, environmental damage.
- **John McEwan** the International Sheep Genomics Consortium Sheep Genome and HapMap Projects
- **Matthew Collins** (University of York, York, UK), told about *PREDICTOR*. This tool is used to evaluate the survival of DNA in bones considering their age and location, using the notion of thermal age based on the burial conditions. He also presented a new protein based identification method developed in York (*Zooarchaeology by Mass Spectrometry; ZooMS*) which can discriminate *Ovis* from *Capra* using collagen peptides.
- **Auli Tourunen** and **Marianna Niemi** presented interim results of the project *The early history of sheep in Finland: combining zooarchaeology, historical sources and aDNA*.

The participants agreed to keep each other updated about the interim outcomes of these various project and to communicate with other scholars in their home countries about these on-going or future research projects related to the topic. A possibility of establishing a blog for discussion was discussed.

4. Final programme

Sunday 16 May 2010

Afternoon *Arrival*

Monday 17 May 2010

- 09.00-09.20 **Welcome by the Director of the Institute of Archaeology**
Stephen Shennan (University College London, London, UK)
- 09.20-09.40 **Presentation of the European Science Foundation (ESF)**
T. Hefin Jones (ESF Standing Committee for Life, Earth and Environmental Sciences, LESC)
- 09.40-10.00 **Introduction by the convenors**
Margarita Gleba (UCL Institute of Archaeology, London, UK) **and**
Caroline Solazzo (BioArCh, University of York, York, UK)
- 10.00-12.00** **Session 1: Archaeology of Wool Textiles**
- 10.00-10.20 **Archaeology of wool textiles and FIBRE project**
Margarita Gleba (UCL Institute of Archaeology, London, UK)
- 10.20-10.40 **Early evidence for wool**
Irene Good (Harvard University, Boston, USA)
- 10.40-11.00 **From raw wool to textile: stages of production**
Linda Olofsson (Trelleborg Museum, Trelleborg, Sweden)
- 11.00-11.20 **The impact of processing methods on analysis of woollen textiles from the archaeological record: points for discussion**
Carol Christiansen (Shetland Museum and Archives, UK)
- 11.20-12.00 **Discussion**
- 12.00-13.00 *Lunch*
- 13.00-15.00** **Session 2: Sheep in Zooarchaeology and Ancient Written Sources**
- 13.00-13.20 **Arrival of sheep in Italy and Sardinia and their development during prehistory**
Barbara Wilkens (University of Sassari, Sassari, Italy)
- 13.20-13.40 **Sheep breed development in Roman times: Integration of Archaeozoological, Ancient Textual and Artistic Evidence**
Michael McKinnon (University of Winnipeg, Winnipeg, Canada)
- 13.40-14.00 **Sheep rearing and wool production in the Linear B tablets (Greece, Late Bronze Age): data and problems**
Françoise Rougemont (CNRS, Paris, France)
- 14.00-14.20 **Sheep breeding in ancient Sumer at the end of 3 millennium BC. Sumerian terminology to the sheep and the organization of animal husbandry**
Marek Stępień (University of Warsaw, Warsaw, Poland)
- 14.20-15.00 **Discussion**
- 15.00-15.30 *Coffee / tea break*
- 15.30-17.30** **Session 3: Fibre Structure and Identification**
- 15.30-15.50 **Hair biology and fibre ultrastructure**
Andrew S. Wilson (University of Bradford, Bradford, UK)
- 15.50-16.10 **SEM fibre analyses: methods, results and limits**
Antoinette Rast-Eicher (Archeotex, Ennenda, Switzerland)
- 16.10-16.30 **Identification of ancient fibres using modern microscopy and diffraction techniques**
Bodil Holst (University of Bergen, Bergen, Norway)
- 16.30-17.30 **Discussion**
- 19.00 *Dinner*

Tuesday 18 May 2010

- 09.00-11.00** **Session 4: Isotopic Tracing**
- 09.00-09.20 **Latest advances with isotopes on sheep during the early stages of domestication**
Carlos Tornero (Universitat Autònoma de Barcelona, Barcelona, Spain)
- 09.20-09.40 **Nature or Nurture? Some thoughts on isotope variation in prehistoric skeletal remains and their implications for sheep domestication**
David Meiggs (University of Wisconsin, Madison, USA)
- 09.40-10.00 **Strontium isotope analysis and wool provenance**
Karin Margarita Frei (University of Copenhagen, Copenhagen, Denmark)
- 10.00-10.20 **A multiple light stable isotope approach to medieval wool samples: what can we learn about trade and sheep husbandry?**
Isabella von Holstein (University of York, York, UK)
- 10.20-11.00 **Discussion**
- 11.00-11.30 *Coffee / Tea Break*
- 11.30-13.00** **Session 5: Proteomics and Genetics**
- 11.30-11.50 **Potential of proteomics for the identification and characterisation of wool in ancient textiles**
Caroline Solazzo (University of York, York, UK)
- 11.50-12.10 **Modern indigenous sheep breeds and sheep domestication**
Miika Tapio (MTT Agrifood Research Finland, Finland)
- 12.10-12.30 **Using retrovirus integrations to reveal sheep domestication**
Massimo Palmarini (University of Glasgow, Glasgow, UK)
- 12.30-13.00 **Discussion**
- 13.00-14.00 *Lunch*
- 14.00-16.00** **Session 6: Genetics and Genomics**
- 14.00-14.20 **DNA survival in modern and ancient wool, and implications for bioarchaeology**
Tom Gilbert (Museum of Natural History, Copenhagen, Denmark)
- 14.20-14.40 **The ISGC Sheep Genome and HapMap Projects: what it means for wool**
John McEwan (AgResearch, Otago, New Zealand)
- 14.40-15.00 **The early history of sheep in Finland: combining zooarchaeology, historical sources and aDNA**
Auli Tourunen and Marianna Niemi (MTT, Agrifood Research, Finland)
- 15.00-16.00 **Discussion**
- 16.00-16.30 *Coffee / Tea Break*
- 16.30-18.00 **Discussion on follow-up activities/networking/collaboration**
- 19.00 *Dinner*

Wednesday 19 May 2010

Morning *Departure*

5. Final list of participants

1. **Margarita GLEBA** (Institute of Archaeology, University College London, UK) - organiser
2. **Caroline SOLAZZO** (BioArch, University of York, UK) - organiser
3. **T. Hefin JONES** (School of Biosciences, Cardiff University, UK) – ESF representative
4. **Carol CHRISTIANSEN** (Shetland Museum and Archives, UK)
5. **Matthew COLLINS** (BioArCh, University of York, UK)
6. **Karin Margarita FREI** (Center for Textile Research, University of Copenhagen, Denmark)
7. **Tom GILBERT** (Natural History Museum, Denmark)
8. **Irene GOOD** (Metropolitan Museum of Art, USA)
9. **Bodil HOLST** (Department of Physics and Technology, University of Bergen, Norway)
10. **Michael McKINNON** (Department of Anthropology, University of Winnipeg, Canada)
11. **John McEWAN** (AgResearch, New Zealand)
12. **David MEIGGS** (University of Wisconsin-Madison, Department of Anthropology, USA)
13. **Marianna NIEMI** (MTT, Agrifood Research Finland)
14. **Linda OLOFSSON** (Trelleborgs Museum, Sweden)
15. **Massimo PALMARINI** (Institute of Comparative Medicine, Faculty of Veterinary Medicine, University of Glasgow, UK)
16. **Antoinette RAST-EICHER** (Archeotex - Büro für archäologische Textilien, Switzerland)
17. **Françoise ROUGEMONT** (CNRS MAE, France)
18. **Stephen SHENANN** (Institute of Archaeology, University College London, UK)
19. **Marek STEPIEŃ** (Department of Ancient History, University of Warsaw, Poland)
20. **Miika TAPIO** (MTT Agrifood Research Finland)
21. **Carlos TORNERO** (Laboratori d'Arqueozoologia, Department of Prehistory, Universitat Autònoma de Barcelona, Spain)
22. **Auli TOURUNEN** (Department of Archaeology, University of Turku, Finland)
23. **Isabella VON HOLSTEIN** (BioArCh, University of York, UK)
24. **Barbara WILKENS** (Dipartimento di Storia, University of Sassari, Italy)
25. **Adrew S. WILSON** (School of Life Sciences, University of Bradford, UK)

6. Statistical information on participants

While textile and fibre research is a research field largely dominated by female scholars, the sciences traditionally have been a male domain. The near to equal participation of male and female scholars in the workshop hence contributed positively to a more equal gender balance in both research fields. The workshop included many young scholars (more than half below 40 years of age), some still writing their PhD (von Holstein, Frei, Niemi). Most participants came from the UK (8 including the two organisers, one of whom is currently on a Marie Curie Outgoing Fellowship in New Zealand and one participant who at the last minute kindly agreed to read a paper by a collaborator from Denmark who was unable to attend due to volcanic ash problems). Other European countries represented were Finland with 3 participants, Denmark with 2 participants, and, with 1 participant each, France, Italy, Norway, Poland (participant invited in response to the comments from ESF grant reviewer about the lack of Eastern European scholars in the preliminary programme), Spain, Sweden and Switzerland. Imperative was the participation of 4 scholars from outside Europe: 1 from Canada, 1 from New Zealand and 2 from the USA (one of whom is currently on a fellowship in Turkey). Humanities and sciences with all relevant fields represented were equally distributed, with many participants having dual and often unique training.

ESF Countries:

Denmark	2
Finland	3
France	1
Italy	1
Norway	1
Poland	1
Spain	1
Sweden	1
Switzerland	1
UK	8 (including 2 organisers)

Non-ESF countries:

Canada	1
New Zealand	1
USA	2

Gender:

Women 13

Men 11

Age bracket:

Below 40: 14

Above 40: 10

Scientific specialty:

Humanities (archaeology, anthropology, history) 11

Sciences (biology, chemistry, physics) 13