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## Flax fibre: Innovation and Change in the Early Neolithic A Technological and Material Perspective

Susanna Harris

### Introduction

This paper was presented in the session “Fibre revolutions; Change and innovation in textile materials and production in the Ancient Old World” organised by Margarita Gleba. The participants of this session were each asked to explore one of the crucial moments in the adoption of new raw materials used to make textiles and their implications in the organisation of societies. This paper presents the evidence for flax and flax fibre in the Neolithic and questions the extent to which the fibre represents a technological, material and social revolution in the Neolithic. The argument focuses on the waterlogged Middle to Late Neolithic lake dwellings of the circum alpine area (Switzerland, southwest France, southern Germany and northern Italy), c. 4200-2800 BC<sup>1</sup> within the wider context of the Ancient Old World.

### Flax in the Early Neolithic

The Neolithic or New Stone Age refers to a broad cultural change across Europe and the Old World<sup>2</sup>. At this time people began to cultivate plants, practise animal husbandry and live a more sedentary life. This “Agricultural Revolution” started in southwest Asia<sup>3</sup> in the ninth millennium BC. It took several thousand years for these farming practices to be adopted through southern, central and northern Europe. The use of domestic plants and animals is considered one of the most profound changes in European prehistory. As well as flax, the first crops (founder crops) include cereals such as emmer wheat<sup>4</sup>, einkorn wheat, barley and legumes including lentil, pea, bitter vetch and chickpea (Zohary, Hopf, & Weiss 2012,1-2). Cattle, sheep and goat were the first domesticated animals. However, the use of sheep and goat hair as fibre does not seem to have been important until the end of the Neolithic, which is several thousand years after the domestication of flax (Rast-Eicher 2005, 119-121).

Flax (*Linum usitatissimum*) was one of the first domestic crops (Zohary, Hopf, & Weiss 2012,100) and represents the earliest known domesticated fibre in the archaeological record. It was domesticated from ‘pale flax’ (*Linum bienne*), a wild plant which grows across southwest Asia, north Africa, western and southern Europe (Adugna 2012,299; Zohary, Hopf, & Weiss 2012,101-3). For archaeologists, preserved domestic flax seeds provide the earliest evidence for the cultivation of the flax plant. Although highly susceptible to decay, the seeds are more likely to be preserved than ancient textiles. Archaeobotanists are able to distinguish between the seeds of domestic and wild flax on the basis of features such as size (Herbig & Maier 2011; Zohary, Hopf, & Weiss 2012,101). The map in Figure 1 shows the location of Early Neolithic domestic flax seeds which have been recovered from excavations, identified by species and recorded by the Cultural Evolution of Neolithic Europe (EUROEVOL)

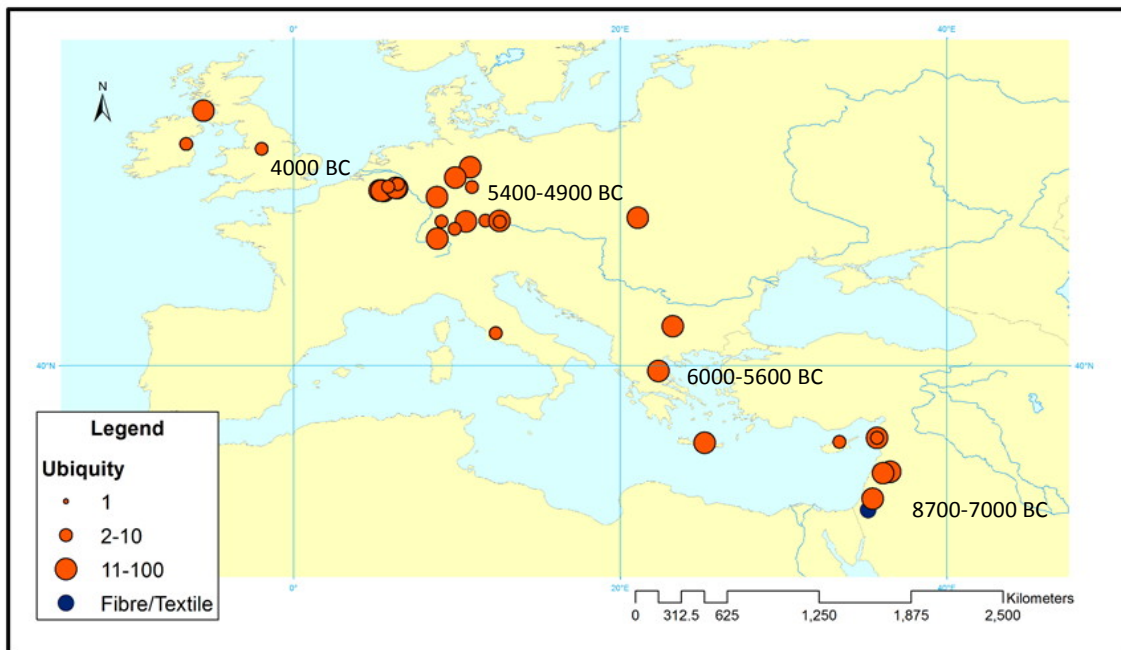
<sup>1</sup> This follows the chronological phases north of the alps; south of the alps the period from 3300 BC is referred to as the Copper Age.

<sup>2</sup> Ancient Old World refers to Europe, western Asia, the Near East and parts of northern Africa.

<sup>3</sup> Also referred to as the Middle East.

<sup>4</sup> Latin names as follows: emmer wheat (*Triticum turgidum* subsp. *diococcum*), einkorn wheat (*Triticum monococcum* subsp. *monococcum*), barley (*Hordeum vulgare*); lentil (*Lens culinaris*), pea (*Pisum sativum*), bitter vetch (*Vicia ervilia*), chickpea (*Cicer arietinum*), flax (*Linum usitatissimum*)

Project, UCL<sup>5</sup>. The orange dots show the presence of domestic flax seeds in Early Neolithic contexts across the Near East and Europe and the approximate date range of these sites in calibrated years BC.



**Figure 1. Location map of Early Neolithic sites with domestic flax (*Linum usitatissimum*). Orange dots = flax seeds; blue dot = preserved textile of which there are only the textiles of Nahal Hemar (Data provided by Sue Colledge, EUROEVOL project UCL, map by Meredith Wiggins © Susanna Harris).**

Flax – referred to as linen when made into textiles - can be grown for fibre or oil, and as a dual purpose crop (Adugna 2012,300). A phylogenetic (DNA) study of the *sad2* locus of domestic and pale flax suggests that the plant was first cultivated for its oil rather than fibre (Allaby et al. 2005,58, 63). It is a matter of detailed analysis in specific areas to determine whether the flax was grown for oil or fibre, this may be determined by a combination of lines of evidence, such as seeds, fibres and tools associated with fibre processing, spinning and weaving (for example Herbig and Maier 2011; Maier & Schlichtherle 2011). The oldest archaeobotanical data for domesticated flax in Europe north of the alps is found in Linearbandkeramic settlements (Karg 2011,2). In the Middle to Late Neolithic alpine lake dwellings (c.4000-2800 BC) of the circum alpine area, uncharred seeds, capsules and large seeds are indicative of the exploitation of the nutrition from seeds (Maier & Schlichtherle 2011). Exploitation of flax for fibre is indicated by processing debris and preserved textiles; and indirectly through fibre processing tools such as heckles or spindle whorls (Maier & Schlichtherle 2011).

The most secure evidence for the exploitation of flax for fibre is preserved threads and textiles where the fibre can be scientifically identified as flax, however such evidence in the Early Neolithic is rare. Some of the earliest preserved and identified linen fabrics in the Ancient Old World are those excavated from Nahal Hemar, a desert cave in Israel; twined

<sup>5</sup> Thanks to Sue Colledge for sharing the data from the EUROEVOL project: [http://www.ucl.ac.uk/archaeology/research/directory/euroevol\\_shennan](http://www.ucl.ac.uk/archaeology/research/directory/euroevol_shennan); European Research Council Advanced Grant #249390

fabric from this site is radiocarbon dated 7065 cal. BC<sup>6</sup> (Schick 1988,31). Those identified as linen include a cloth constructed in open twining, tassels and needle-netting, although there are no plain weave textiles at Nahal Hemar. Such evidence demonstrates that flax was being used for its fibre from the Early Neolithic Pre-Pottery Neolithic B (PPNB) in the southern Levant. In the circum alpine area of Europe the earliest preserved linen cords, nets and textiles come from Middle to Late Neolithic alpine lake dwellings (Barber 1991, 11-15; Médard 2012, 386-9; Rast-Eicher 2005, 118-20), which is roughly two thousand years after the earliest flax seeds in the same area. Flax fibres used for non-woven fabrics are known from the Early Neolithic in the Near East. However, as most areas lack preserved Early Neolithic textiles or cordage it is unclear at which point in the Neolithic that flax was first exploited for fibre.

### **Indigenous and domesticated; foraged or farmed?**

Archaeologists debate how, when and why people chose to adopt a predominantly farming lifestyle and the effect of these changes on human societies. This transition from foragers (Mesolithic) to farmers (Neolithic) has been hotly debated over many decades, with arguments based on progress, economy, population growth, colonization, acculturation and ideology (see summary in Barker 2006, 1-38). The complete separation of farming and foraging lifestyles is increasingly criticised in the face of evidence that such activities were practiced simultaneously (Cummings & Harris 2011). The domestication of flax and use of flax fibres was part of this bigger change in economy and society. In this sense, flax fibre is part of the major changes in the organisation of society in the Neolithic as people across the Ancient Old World came to depend on domestic crops. However, the use of what we may call foraged plant fibre resources before, during and beyond the Neolithic is also evident when considering fibres and raises questions as to the extent fibres were foraged or farmed.

In the Neolithic and later periods, domesticated flax fibre was used alongside fibres from indigenous plants including reeds, grasses and bast fibres from trees. Plants with pliable stems are used with little processing using the whole stem, while tree bast fibres are harvested as strips from the inner bark of species such as lime, elm, willow, poplar and oak (Figure 2 & 3). These indigenous species are common and can produce ample fibres. These species of trees are indigenous to much of temperate Europe and western Asia (for distribution today: Russell et al. 2007, 336, 352, 368, 372, 376). The small-leaved lime (*Tilia cordata*), for example, is particularly noted for its good quality bast fibres and grows across much of Europe from Southern Scandinavia to Portugal and the Caucasus (Russell, Cutler, & Walters 2007, 368-9). In the Neolithic (and other periods), indigenous fibres are only securely identified from preserved fibres, making them highly elusive in the archaeological record; fibre processing tools are usually too generic to associate with a particular fibre, and archaeobotanical data can only point to the presence of fibre rich species, not the way they were used. For this reason knowledge of indigenous plant fibre use is scarce and remains attested only at sites with suitable preservation conditions.

That tree bast fibre and grasses were used by foraging societies is attested by preserved looped cloth of Late Ertebølle (Mesolithic) foragers of southern Scandinavia c.4200 cal.BC (Harris 2014,41-43). Fibre analysis of the looped cloth from Tybrind Vig, Denmark identified

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<sup>6</sup> Nahal Hemar, twined fabric (OxA 1015) 8500 ± 220 BC; 7065 cal.BC with 95.4% certainty. Calibrated with OxCal 4.2.

the predominance of fibres from tree species, mostly willow bast (*Salix* sp.) with some lime (*Tilia* sp) and possibly poplar (*Populus* sp.) as well as grasses (Gramineae) (Andersen 2013, 215-216; analysis by Körber-Grohne in Bender-Jørgensen 1990, 2). That these indigenous



**Figure 2. Left: Location of tree bast fibres in cross-section (image © Susanna Harris).  
Figure 3. Right: Processed lime bast fibres (image © Susanna Harris).**

sources of fibre were used by farmers alongside flax fibre is attested by their abundant use for cords, ropes, nets and twined clothing in the Middle to Late Neolithic alpine lake dwellings in sites dated from the late fifth millennium to third millennium BC (Rast-Eicher 2005, 118-119; Rast-Eicher 1997, 302-303). Indeed overall, there are more preserved cords, threads and



**Figure 4. Left: Modern flax field (*Linum usitatissimum*) with harvested crop dew-retting in the foreground (Image © Susanna Harris).**



**Figure 5. Right: Lime trees (*Tilia* sp.) – the source of lime bast fibres (Image © Susanna Harris).**

cloth from tree bast fibres than those of flax (Médard 2010,57). Here, tree bast fibres of lime, oak and willow were the main fibres used to make twined cloth (Médard 2010,57). Lime bast and grasses were also a key component of the clothing and equipment of the frozen Iceman (c.3300 BC) found in the high Alps (Pfeifer & Oeggl 2000; Putzer 2011, 33-34). Fibres, possibly tree bast, were recovered from Early Bronze Age levels at Molina di Ledro, Italy (Bazzanella & Mayr 2009; 124).

Flax is a domestic plant which was cultivated in field or garden systems (Figure 4). This contrasts to fibres foraged from indigenous plants (Figure 5). The extent to which trees were managed for fibres remains unknown. Historically (mid 1800s) in Europe lime was managed for bast production (Körbe Grohne & Feldtkeller 1998, 156). Many of the bast producing tree species (lime, oak, willow) can be coppiced, which encourages new, straight growth suited to fibre exploitation. Whether gathered on a more ad-hoc basis, or procured from more

<i>Flax</i>	<i>Whole stems</i>	<i>Tree bast</i>
Acquire seed ↓ Prepare the ground; dig / plough, remove stones, weed, manure ↓ Sow seed ↓ Tend plants; water, weed, pest control ↓ Harvest by pulling plants ↓ Collect in bundles ↓ Store or process immediately	Locate plant ↓ Harvest by cutting stem or pulling up whole plant ↓ Strip the leaves, seeds and other unwanted elements ↓ Store or process immediately	Locate tree ↓ Select suitable branches or trunk ↓ Remove the smaller branches and shoots ↓ Cut through bark to facilitate its removal from heartwood ↓ Pull strips of bark from the tree ↓ Store or process immediately

**Table 1. Suggested chaîne opératoires (operational sequences) for the procurement of fibres; flax, tree bast, grasses and stems (Harris 2007;64-69 fig. 4.1.1.-4.1.4).**

systematically managed resources, the use of indigenous fibres demonstrates different technological choices in the procurement of domesticated and indigenous plants; these can be compared by thinking through the *chaîne opératoires* (operational sequences) of fibre production (Table 1). The cultivation of flax shows that some Neolithic farmers were willing to prepare fields, sow, tend and care for the plants to obtain a fibre crop. At the same time they exploited other plant resources by foraging. This forage and farm approach to fibre in the Middle to Late Neolithic alpine lake dwellings demonstrates a combination of fibre procurement strategies.

### **Fibres and materials**

How do these fibres compare as raw materials and in the materials they constructed? Bast fibres from annual plants such as flax, and tree bast are made from cellulose and therefore share many properties. Cellulose fibres have low elasticity and are highly flammable (Collier & Tortora 2001, 61; Harris 2010, 106-107). There are also differences between cellulose fibres, in terms of physical, chemical, aesthetic and mechanical properties (Table 2). Lime

bast, for example, floats and has low water absorption so does not swell in contact with water; its use in Medieval ships' rigging attests to its strength (Myking et al. 2005, 69-70). Aesthetically, the natural colour of flax ranges from white, yellow, reddish to silver grey. Tree bast fibres are darker, typically from light to medium golden brown. Flax continues to be appreciated today for its strength, fine long fibres and softness (Collier & Tortora 2001, 77). As yet there are no published results comparing tree bast fibres and flax<sup>7</sup>. From practical experience working these fibres, one is aware that tree bast fibres are physically coarser than flax, although tree bast can also be processed into relatively fine strands. Indeed, plied threads of tree bast 1.3 mm in diameter were used to make a twined cloth at Late Neolithic sites in Arbon Bleiche 3, Switzerland (Leuzinger 2002, 134).

<i>Fibre</i>	<i>Properties</i>	<i>Details</i>
Lime bast	Mechanical	Stronger than elm or oak bast, particularly if unretted Low elongation Low resistance to wear Low water absorption Floats on water
	Chemical	Resistant to decay
	Aesthetic	Natural colour: light to medium golden brown
	Handle	Soft when retted Cool
Flax	Mechanical	Good tensile strength Brittle, breaks under repeated flexing Low elongation Resists abrasion Highly flammable
	Chemical	Only susceptible to mildew in very moist conditions Resists acids, bases and chemicals bleaches
	Aesthetic	Dull fibre, more lustrous if beaten Natural colour: white, yellow, reddish, silver grey Accepts dyes; mordant improves fastness
	Handle	Soft Cool Crisp Smooth

*Table 2. Selected properties of flax and lime bast fibres (collated sources previously published in Harris 2010, 106-107, tables 18.2 & 18.4).*

When considering the way the fibres were used, it is evident that in the alpine lake dwellings flax and tree bast fibres were used in overlapping but contrasting ways. Analysis of the fibre of numerous cords, textiles and basketry by Fabienne Médard has shown the two main fibre resources of flax and tree bast (lime, willow, oak) were used in different ways (Médard 2012,368 ). Typically tree bast fibres were used for cords (1-3mm diameter) and thick cord (over 3mm diameter) and only rarely fine threads (less than 1mm diameter); by contrast flax was reserved for fine threads of less than 1mm in diameter (Médard 2003, 80-83). There is a relationship between the raw material (fibre) and the type of cloth produced. As stated above, tree bast fibres (predominantly lime) were mostly used for twined cloth whereas flax was mainly used for woven textiles (Médard 2012,368). As can be seen from the evidence of the Middle to Late Neolithic alpine lake dwellings, tree bast was predominantly used for coarser threads and twined cloth, whereas flax was used for fine threads and woven textiles. Such a

<sup>7</sup> New results comparing the mechanical properties of flax, lime and willow bast are currently in preparation for publication with colleagues W.Sampson, S.Haigh and A.Handley at the Manchester School of Materials.

distinction appears to relate to the physical nature of the fibres, but the cross-over between the materials and techniques also suggests a cultural relationship between materials and products.

## **Conclusion**

To what extent does flax fibre represent a technological, material and social revolution in the Neolithic? Flax was the first domestic plant to be grown over wide areas of Europe. For this reason it represents an innovation in the potential range of raw materials to make textiles. However, it is questionable when and how flax fibres were used in the Early Neolithic, mainly due to the extreme rarity of preserved fibres of this antiquity and the evidence is best addressed on a region by region basis. The domestication and cultivation of the flax plant was part of a bigger change in economy and society, referred to as the agricultural revolution. In this sense, it is part of wider social changes that occurred over several thousand years across the Ancient Old World, the nature of which is still debated. As much of the evidence brought to these debates focuses on food stuffs, it is key to bring in the evidence for cultivation for flax fibres and the presence of significant quantities of foraged plant fibres. Evidence from the Late Neolithic alpine lake dwellings demonstrates the long tradition of continued use of indigenous plant fibres alongside domesticated flax.

If we consider fibre procurement from a technological perspective, the presence of yarns and textiles made of flax shows that some people were willing to prepare fields, sow, tend and care for the plants to obtain the fibre crop; such farming practices were commonly used to grow foodstuffs. However, people did not give up on the opportunity to forage for fibres from indigenous plants such as reeds, grasses, and tree bast; indeed in the Late Neolithic alpine lake dwellings, such fibre use exceeds that of flax. The extent to which the indigenous fibre resources were managed (for example by coppicing) or foraged on a more ad-hoc basis is unknown. That these alternative schemes of obtaining fibres were practiced concurrently over many generations (from the Neolithic into later periods) shows that foraged and farmed fibres were both key resources.

To what extent was the introduction of flax fibre a material revolution? Plant (cellulose) fibres, whether farmed or foraged, were familiar. In this sense then, the first appearance of flax may not represent a revolutionary change or innovation from a time when people relied on foraged plant fibres, indeed some properties and processes would have been familiar. That distinct traditions of working flax and tree bast fibres arise in the Late Neolithic alpine lake dwellings of the circum alpine region may in part have been due to the physical properties of flax with its long, fine fibres which were found to be well suited to weaving. However, innovation and change could equally be answered through an ideological relationship between traditions of working flax and those of working tree bast fibres. The evidence for fibres in Neolithic Europe adds a novel dimension to the wider arguments for the relationship between foraging and farming in the Neolithic, demonstrating that where fibres are concerned both strategies were practised.

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