PART I

BACKGROUND
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Historic Usage and Preservation of Cultural Heritage

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1.1 Introduction

The responsibility of preserving our material heritage heightens our awareness of our cultural history. Historical textiles are made from natural fibres and serve to create a special link between the natural environment and the social environment that underlies all our lives, from the everyday textile to patriotic to ceremonial. Understanding and identifying natural historic textile materials helps assure that these textiles are preserved for future generations. The application of a range of scientific techniques to fibre analysis provides a wealth of information for textile preservation (France, 2005a). A historical textile consists not only of the material itself but also of all the historical evidence collected upon and within it over years of use. Scientific analyses can establish whether surface contaminants and soiling have historical significance or are potential sources of degradation. For cultural heritage institutions (including museums, libraries, archives and historic house collections) this involves additional critical details concerning display, storage, exhibition and treatments, including details about soiling, deterioration and the effects of environmental conditions. Techniques such as scanning electron microscopy, X-ray analysis, confocal microscopy, gas chromatography, mechanical testing and chemical analyses allow investigations into internal and external aspects of the fibre structure, identification of surface contaminants and the opportunity to learn about the impact of treatments and display environments on textile deterioration. This microscopic-level examination in turn reveals macro-level information pertaining to the condition of the entire textile.

1 The views presented in this chapter reflect the opinion of the author and not the Library of Congress.
1.2 Preservation of Cultural Heritage

The historic use of natural fibres is much broader than clothing and tapestries, as they heralded patriotism, sovereignty, peace and all too often war when structured into woven fabrics. Finely woven wool fabrics were utilised as banners and large flags, as they were robust and could be dyed to required colours, with the loose-weave structure allowing them to brandish the symbol of the message, even in a large format. Preserving our past requires knowledge of the properties of the textiles from which they are formed (France, 2005b). The ubiquitous nature and functionality of textiles give them a unique place in our cultural heritage. Unlike works of art and other items, textiles are generally made to be functional, so that, after normal wear and tear, they enter our museums already in a fragile state. This also has implications for their documentation, or lack thereof. Gaining knowledge of the unique natural fibre textile properties and structure can be accomplished with a range of scientific analyses and techniques.

While highly significant and recognisable items such as the United States’ Star-Spangled Banner are noted to have been present at certain events – in this case the battle at Fort McHenry in Baltimore harbour in September 1814 – detailed knowledge of their history is often sketchy. This historic flag was commissioned by Major George Armistead, commander of Fort McHenry, and was raised over Fort McHenry on the morning of 14 September 1814 to signal American victory over the British in the Battle of Baltimore. It was this event that inspired Francis Scott Key to write ‘The Star-Spangled Banner’, the song that became the United States’ national anthem. The original flag was 9.1 m by 12.8 m (30 ft by 42 ft) and made of high-quality single-weave wool bunting and cotton. Each of the fifteen stripes in red and white (undyed) wool were 0.6 m (24 in) wide, the same width for the wool in the blue canton, and the fifteen large cotton stars measured 0.6 m (2 ft) point to point. The history of this woollen flag fabric can be traced back to a cottage industry in Sudbury, Suffolk, England, in the late eighteenth century (France, 2007). This artefact provides us with an excellent example of the impact, potential and challenges offered by science and technology for studies into the textile structure and properties of cultural objects. Scientific techniques and new technologies are proving critical for providing previously lost information, information that informs us as to both the current state of the artefact and the main sources of degradation, as this information is paramount for establishing the optimum environmental conditions to ensure the long-term preservation of a historic technical textile such as a flag.

The determination of chemical and mechanical properties and fabric, yarn and fibre morphology start to provide this knowledge. A historical textile consists not only of the material itself but also of all the historical evidence collected over its years of use. Determining the probable source of surface contaminants is critical, as soiling offers curators evidence linking a textile to a particular geographical location, or can reveal trace elements from a particular historic event, such as the War of 1812. Scientific analysis supported by microscopy helps establish whether surface particulates, contaminants and soiling have historical significance, and aids in critical decisions regarding possible degradation from surface contaminants that could reduce the artefact’s life.

Assessment of the amino acid content of the wool fibres allows identification of the specific amino acid composition characteristic of the specific breed of sheep or domestic animal (see Chapters 12 and 16). Historically, many cultural heritage items had pieces removed over the years. For example, when soldiers who fought at Fort McHenry died, their widows wrote to the daughter of the commander of the fort, requesting a piece of the Star-Spangled Banner to be buried with their husband. Amino acid analyses of samples found later in various locations were tested to assess and confirm their provenance against the amino acid composition of the flag keratin. Changes in specific amino acid analyses can also confirm the main agent of deterioration (e.g. light or temperature), as specific amino acids will degrade under certain conditions while others are left unchanged.

Scanning electron microscopy (SEM) and elemental analysis are pertinent techniques for assessing the effects of surface deterioration to support curatorial decisions. SEM provides insights into fabric, yarn and fibre fracture morphology, which illustrates changes due to photodegradation, through high-resolution high-magnification images. At the fibre level, these highly magnified visible changes, linked with specific
mechanical and chemical behaviour in the keratin structure, lead to a commensurate decrease in the textile’s mechanical strength, as the fibre fracture is a direct manifestation of changes in the internal structure that reduce the mechanical properties.

Changes in fibre surface morphology evident in SEM images provide strong indicators of the effects of various degradative environmental influences – light, relative humidity, biological and soiling. This fibre degradation is indicated by the presence of microfractures and cracking from relative humidity fluctuations, abrasion from particulates and/or damage from biological organisms. Analyses by SEM allow confirmation of the high sulphur content characteristic of wool, as well as determination of any surface contaminants that can provide further historic information relating to the historic context, sometimes geographical information and size and composition of degradative particulates and soiling (France, 2003a).

The SEM micrograph in Figure 1.1 shows a relatively smooth fracture surface, indicating light damage, and a lack of scale structure, indicating both age and damage from usage as a technical textile. Further morphological details illustrate the presence of microfractures in the fibre, probably owing to environmental fluctuations and the expansion and contraction of organic natural fibres from moisture changes, and the lodging of small particulates in these microfractures, which exacerbates the fracture and leads to breaks and deterioration of the textile. The basic theory regarding fibre fracture in extension involves the propagation of a crack from a flaw (Andrews, 1964). The influence of flaws on the tensile properties of natural fibres will be discussed in more detail in Chapter 13. In aged wool fibres, deterioration has already occurred owing to the effects of use and exposure to the environment. Changes in relative humidity cause small changes in fibre dimensions, which, when constantly repeated, slowly generate microscopic flaws in the wool fibres. Modern fracture mechanics has established that fibre breaks can initiate from a microscopic flaw present in the fibre structure, with axial shear deformation playing an important role in the initiation and propagation of cracks.

Figure 1.2 illustrates the soiling that is prevalent with historic natural wool fibres, but also the fact that, through shielding within the textile yarn structure, some fibres may retain scale formation. Therefore, it should be noted that, while some fibres may be so degraded as to require amino acid analysis or chemical testing to confirm their substrate, there can be a range of fibre morphologies within natural historic fibre assemblies. However, the microfractures – albeit smaller – are still in evidence, with small particulate material lodging in the fractures and leading to exacerbated damage and deterioration of the natural fibres.
For conservation specialists and cultural heritage collections, preventive conservation requires analyses that include additional critical details about display, storage, exhibition and treatments. These investigations must include information about soiling, patterns and levels of deterioration and the effects of environmental conditions – such as relative humidity, light levels and pollution control. The application of a range of scientific techniques to fibre analysis provides a wealth of information for textile preservation. Techniques such as SEM, elemental analysis, confocal microscopy, light microscopy, gas chromatography (GC-MS), mechanical testing and chemical analyses allow investigations into internal and external aspects of the fibre structure, identification of surface contaminants and the opportunity to learn about the impact of various treatments and display environments on textile deterioration (France, 2004).

Linking chemical and mechanical properties allows changes in the fibre properties to be associated with physical changes in the technical textile. While much attention is paid to temperature, organic materials are highly susceptible to changes in relative humidity, as indicated by the micrograph in Figure 1.2. Wayne (1970) noted the basis for distinguishing between photochemical and thermal effects. This can be highlighted by the example of a bond-breaking reaction that requires energy of 251 kJ/mol, typical of many covalent bonds in wool fibres. The excitation energy to break this bond can be induced photochemically by a single quantum of light of about 450 nm (i.e. green light). In contrast, at ambient temperatures the thermal energy available for bond cleavage is essentially zero ($4 \times 10^{-16}$). The state of historic wool fibres is dependent upon the extent to which the textile item has been used, and the conditions to which they have been exposed: light, water, oxygen and temperature. A study of keratin fibres taken from tombs in Egypt dated at between 1500 and 4000 years old showed that these retained as much as 20% of the strength and 10% of the extensibility of modern unaged wool fibres (Massa et al., 1980). These values were also comparable with those of wool fibres only 200 years old from textiles that had been used as working textiles, and that had spent a portion of their recent history in museum environments. To gain an accurate assessment of the state of deterioration of historic natural fibre assemblies, the use of the ‘energy of rupture’ measure provides a combination of both the loss of strength and the loss of extensibility of the aged fibres. As shown in Figure 1.3, pre-Columbian wool textile fibres (ca. 1500) that had been buried under conditions of constant relative humidity, low oxygen and no light were shown to retain up to 50% of the strength of unaged wool fibres, as compared with textiles from 1800 that had been exposed to environmental fluctuations. This shows the significant effect of environmental conditions on the preservation of these textiles.
parameters on historic wool textiles. As is evident from the steep initial portion of the curve, extensive degradation occurs early in the life of a textile; therefore, as regards the degradation process of natural fibres, the preservation of modern natural textiles needs to be carefully considered in terms of their exposure to degradative environmental influences (France et al., 2005).

The primary goal of conservation is the preservation of cultural property, with current preventive conservation focusing on non-intervention techniques if possible. An important consideration is whether stabilisation of conditions alone can confer enough of a benefit to offset the requirement for treatment to the historic textile artefact. If treatment of the textile is required to remove harmful contaminants, an evaluation of the treatment is necessary to ensure that it both confers a benefit by removing soiling and particulate matter and does no harm through fracturing or decreasing mechanical properties. In order to create a baseline for many of these tests, samples that have undergone accelerated ageing are usually utilised to assess the various potential environmental conditions and treatments. In these cases, removing samples from an already fragile historic textile for assessment is an ethical dilemma. Very small samples that can directly answer critical questions for the long-term preservation of the item may be permitted; however, preservation scientists are constantly developing non-destructive, non-invasive techniques that can provide the same level of information without any impact on an item of significant cultural heritage (France, 2003b). This assessment of treatments and environmental parameters supports critical cost-benefit decisions while providing a more comprehensive overview of preservation requirements.

Characterisation of natural fibres is a critical component in assessing the overall properties of the product, as what occurs at a micro level can have a significant impact on the effects observed at a macro level and the applicability of the fibre for specific uses. The determination of chemical and mechanical properties is critical for cultural heritage, as often there is little documentation and it is only through scientific analyses of the fibre and fibre structures that a historical profile can be recreated. Many techniques in conservation science focus upon microsampling as non-invasively as possible, causing minimal disturbances to an already fragile textile. Changes in chemical properties can give a good assessment of structural damage and deterioration of the natural fibres, particularly when these are linked with physical markers that integrate this micro-level information with the macro-level manifestation. Significant interest is again being shown in the analysis of both animal and plant natural fibres because of their inherent properties, providing a template for the creation of man-made fibres. These can include bicomponent structures such as wool, or specific moisture, strength and extensibility properties such as those for cellulose and protein fibres. The utilisation of these natural fibres in long-term applications such as technical textiles will continue to play a significant role in the preservation and understanding of our cultural heritage as well as in future developments for sustainable and environmentally compatible textiles.
As mentioned previously, the stars of the Star-Spangled Banner were made from cotton fabric, and these exhibited a higher level of acidity than the wool fabric. Stabilisation of the cotton fabric was part of the conservation treatment, as well as removal of a linen backing attached in 1913 to stabilise the flag. The linen backing and Amelia Fowler stitching stabilisation undertaken in 1913 was removed, as the bast fibres (Figure 1.4) were degrading at a different rate to the wool fabric and causing destabilisation of the wool and cotton flag structure. It should be noted that all natural fibres have different properties with regard to strength and extensibility, so composite fabrics – whether historic or modern technical textiles – need careful attention as to the combination of fibre properties.

1.3 Conclusion

Studies of the history of historic textiles and their natural fibres provide additional insights into the technical applications of the textiles over the years. The stewardship of historic textiles, in common with all cultural heritage items, requires the best preservation techniques possible to ensure their longevity based on current information and resources. This requires an understanding of the history of the textile in terms of its lifetime of usage, display and storage environments, technical application and the effects of treatments and conditions. The current state of a natural fibre textile will be entirely dependent upon this history. As this is often not documented, a range of analytical techniques are essential to provide the missing information, including by testing the properties of the natural fibres. This critical information should include not only the mechanical and chemical state of the textile, together with fibre and dye analysis and identification, but also the level and type of environmental degradation that have occurred. Identification of soils and contaminants, as well as an assessment of those treatments that are most beneficial for the preservation and understanding of this textile, is also important. While a wide variety of analytical techniques are available, a clear understanding of the information required for conservation of each textile should be established, so as to utilise the most appropriate technique to answer the conservation questions and determine the optimum preservation outcome or treatment.

Conservation requires scientific analyses for conservation specialists and museum collections that provide critical details for identifying a natural historic textile – history, display, storage, exhibition and treatments.
These investigations must include information about soiling, patterns and levels of deterioration and the effects of environmental conditions – light levels, relative humidity and pollution control. The application of a range of scientific techniques to textile fibre analysis provides a wealth of information for textile preservation. The advanced precision in techniques such as mechanical testing, chemical analyses and microscopy allows investigations into internal and external aspects of the fibre structure, identification of surface contaminants and assessment of textile deterioration linked to environment or treatment. In the museum setting, conditions can be controlled and monitored to minimise the effects of environmental factors.

The primary goal of conservation is the preservation of cultural property, with preventive conservation focusing on non-intervention techniques if possible. An important consideration is whether stabilisation of conditions alone can confer enough of a benefit to offset the requirement for treatment of a historic artefact. If treatment of a textile is required to remove harmful contaminants, an evaluation of the treatment is necessary to ensure that it both confers a benefit by removing soiling and particulate matter and does no harm through fracturing or decreasing mechanical properties. Preventive textile conservation extends the life of a textile with the best care available. This involves making decisions about exhibition and storage conditions, monitoring and controlling the environment and treating or cleaning the textile. Critical information is necessary to make these informed decisions. The use of available and well-developed scientific techniques provides those involved in conservation activities with the empirical information needed to understand the properties of the natural fibres and to make these critical decisions about preservation.

References
