Textile conservation


Textile conservation – introduction


Textile conservation – the structure of cotton and linen


Textile conservation case study – the Victory sail

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A textile is any filament, fibre, or yarn that can be made into fabric or cloth but the word 'textile' also refers to the fabric or cloth itself. Textiles can be used to make a wide range of products – probably the most obvious is clothing, but others include car interiors, yacht sails, furnishings and the wings of early aircraft to name just a few.

Textile conservation can be an interesting context within which to teach organic chemistry because the topic covers both fibres known from ancient times, such as cotton and linen, and modern materials like PVC and rubber.

Conservators are used to dealing with the traditional materials and have various tried and tested methods for the conservation of such materials at their disposal. Modern materials often present more of a challenge because the way they decay is poorly understood. Research is currently underway to find the best methods for preserving what may become important cultural artefacts for future generations.

In this resource

- **Suggested starter activities:** A selection of introductory activities (see below).
- **Textile conservation – introduction:** A short introduction to some of the issues in textile conservation
- **Textile conservation – the structure of cotton and linen:** Organic chemistry in the context of textiles. Two student sheets are provided – a question sheet and a diagram sheet.
- **Case study – the Victory sail:** Infrared spectroscopy in the context of conservation. The material includes information on recent research carried out at the Textile Conservation Centre in Winchester. Some prior knowledge of general and organic chemistry is required for this activity and students have the opportunity to apply what they learnt from the exercise on the structure of cotton and linen.

Suggested starter activities

There are a number of ways in which this topic could be introduced and it is recommended that you do at least one of the following starter activities before attempting the other work provided in this resource. Several of these starters could be combined to form the basis of a satisfying unit of work for less able students on 'materials and their properties'.

- Show a series of images of costumes/textiles from different time periods and ask students to discuss their reactions to the pictures. You could include 1960s 'flower

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power' style items, 70s brown flares, 80s shoulder pads, pictures of assorted current celebrities (perhaps with their faces blanked) etc. Try and include the 'yuck' factor and the 'wow' factor.

- Provide students with a set of garments or other textiles (charity shops are good sources of these) and ask them to decide what each item is made of and where the material in question came from. For example, a blouse might be made of polyester with cotton thread and have plastic buttons. Polyester and the plastic used for the buttons are made from petrochemicals; cotton comes from a plant. Clothing labels can be helpful but include a few items without labels to stimulate discussion. Students could be asked to think about the following questions: How could you find out what the fabric is made of? How would museum conservators do so?
- Cover two display boards with matching samples of various materials in a range of colours. You could include materials such as silk, delicate cotton, more robust cotton, velvet, PVC, polyester. Put one board somewhere where students can touch the samples and encourage them to do so. After a couple of weeks, compare the untouched samples with those that have been handled.
- Collect samples of a variety of fabrics in different colours and cut each in half. Hang one half in a sunny window and leave the other half in the dark. In the summer months a change can be observed within a couple of weeks – for best results leave the samples for a couple of months. Note which colours have faded the most. This experiment can also be done with sugar paper. Instead of using two pieces of each colour, attach a square of thick card to the centre of each piece of sugar paper. The change of colour can be seen where the paper was left uncovered but no change occurs in the square that was protected from the light by the thick card.

Answers

Textile conservation – introduction

1. A damp atmosphere would make the textile heavier.
2. Delicate fibres may break if the weight they are supporting increases.
3. As you heat an object it expands; as it cools, it contracts.
4. If the textile has dust between its fibres and the temperature changes, the dust acts as an abrasive and rubs against the fibres as they expand and contract and move over each other. This can cause the fibres to break. Without the movement caused by a temperature change, dust particles can do less damage. A temperature change in the absence of dust only causes the fibres to rub against each other so the damage is less severe.
5. Textiles in museums are often displayed in glass cases because this keeps out dust and prevents people from touching the items. The glass also helps to limit any temperature changes that might take place within the case. The light level is kept low to minimise the amount of damage done to the dyes in the textiles and to prevent the colours from fading.

Textile conservation – the structure of cotton and linen

1. (A copy of the cellulose structure is supplied as part of the student sheets).

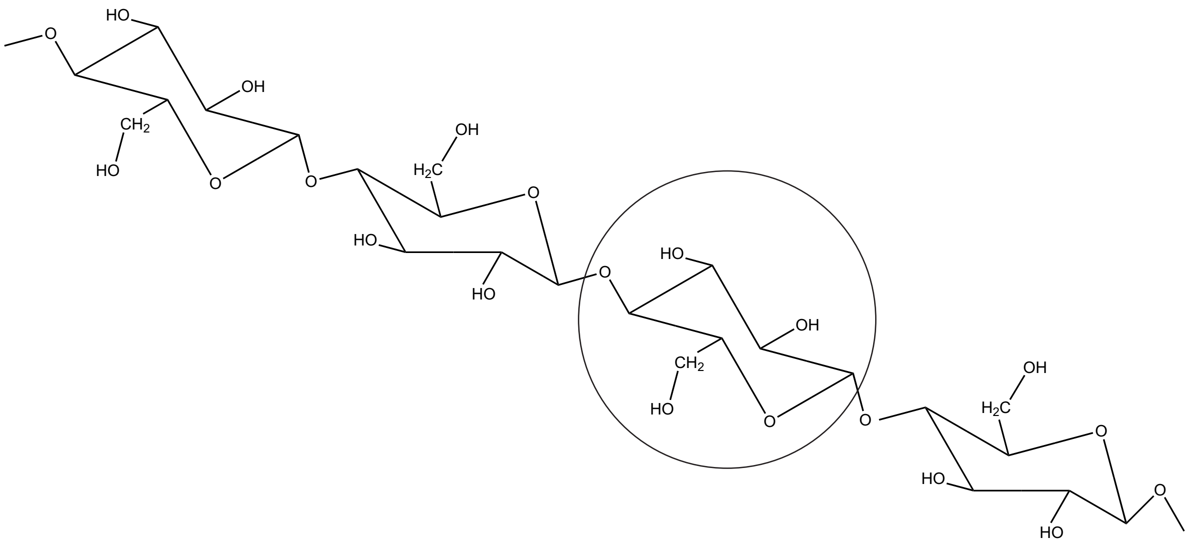

Figure 1 The circle marks one cellulose monomer

2. Starch is unable to form fibres because it has branched chains. The branches prevent the chains from lining up in an ordered way so they cannot form a long ordered crystal (*ie* a fibre).

3. If the water was removed from linen it would become brittle and would be more likely to break.

4.

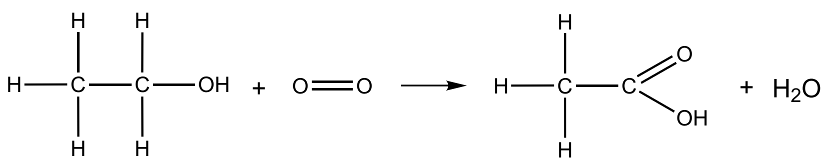

Figure 2 Reaction of ethanol with oxygen

5. This is an oxidation reaction. Oxygen is added to the ethanol and hydrogen is removed.

6. The organic molecule is ethanoic acid.

7. It contains a carboxylic acid group.

8. Solutions containing hydrogen ions are acids.

9. The presence of H^+ ions will increase the rate of this reaction.

10. Catalysts take part in the reaction but are not used up during it. This means they can be re-used so they can take part in several reactions. Since the H^+ ions are not used up when they catalyse the polymer breakdown, they can do more damage than if they reacted with the textile (which would use them up).

11. This reaction will make the textile far more fragile and weak because it breaks down the long chains which give the material its strength.

12. An alkali would react with the H^+ ions and remove them.

13. Conservators use anionic or neutral detergents because the fabric is slightly negatively charged as a result of the damage caused by oxygen. Cationic detergents would be attracted to the fibres and would not be washed away. This would change the chemical make-up of the textile. Anionic and neutral detergents are not attracted to the fibres so they can be washed away easily.

14. This is only a temporary solution because the bonds formed by the cations are not very strong. Also, the fabric will continue to be oxidised if it remains exposed to air and there will be no calcium or magnesium ions available to react with the newly formed negatively charged groups.

15.

$$H^+ + NH_3 \rightleftharpoons NH_4^+$$

16. This is only a temporary solution because the reaction is reversible. Given time, the NH_4^+ ion will turn back into ammonia and hydrogen ions.

17.

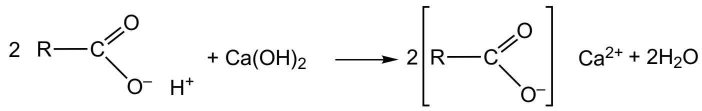

Figure 3 Reaction of a damaged fibre with calcium hydroxide

Case study – the Victory sail

1. It was important to vacuum the sail to get rid of dust (and fungi spores). Dust acts as an abrasive and damages the fibres, especially when the sail is moved.

2.

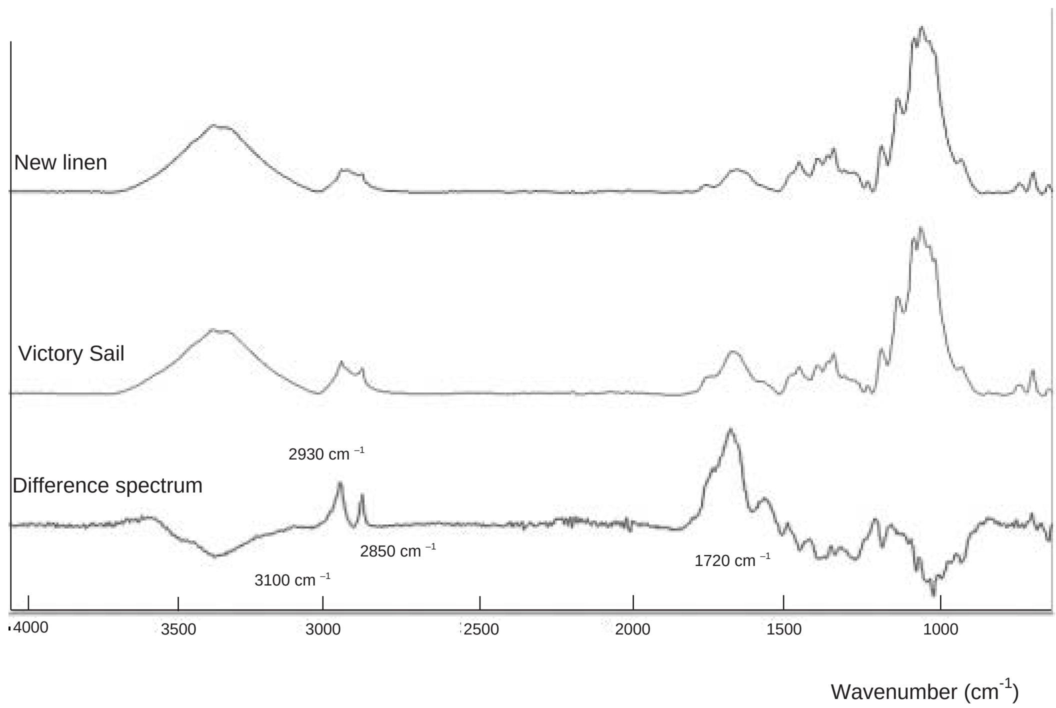

Figure 4 Linen spectra and difference spectrum

3. The band at 1720 cm^{-1} in the difference spectrum supports the idea that the linen has been oxidised because it shows that the oxidation product (the old sail) contains C=O groups but the new linen does not. If the formula shown in **Textile conservation – the structure of cotton and linen** is correct, then the original linen contained alcohol groups but no carbonyl (C=O) groups. The carbonyl groups must have been produced by oxidation.

4. Yes, this band confirms that the reaction has occurred. If the number of carbonyl groups has increased as a result of oxidation of alcohol groups to carbonyls, then the number of alcohol groups present should have decreased. The spectrum shows that this is the case, which further supports the idea that the linen is being oxidised.

5. The more damage that has occurred (at least in terms of oxidative damage), the more carbonyl (C=O) groups there will be in the linen – *ie* the peak at 1720 cm^{-1} in the difference spectrum will become more pronounced as the damage increases. At the same time, the number of alcohol groups present will decrease – *ie* the band at 3100 cm^{-1} will become even more negative. If these bands are only shallow, the linen being tested is very similar to new linen and not much damage has occurred. If the bands are very marked then a lot of damage has occurred and the old linen is very different from new linen. The damaged old linen will be more brittle than new linen and extra care will be needed when handling it.

Textile conservation – introduction

A textile is any filament, fibre or yarn that can be made into fabric or cloth, but the word ‘textile’ is also used to mean the fabric or cloth itself.

Textiles are important to us and throughout history people have used them as a way of expressing personality and status. They are used in clothing, decoration of accomodation, flags and banners, the interiors of cars and in many other ways.

Textiles can also have very important protective functions – firefighters need non-flammable uniforms; members of the armed forces often rely on bullet-proof clothing to protect them when they are at work.

Textiles are an important part of our culture. Future historians will examine the textiles of today to find out about who we are, how we live and what we value, just as we look at the textiles of previous generations to find out about them.

Most textiles, however, are not designed to last forever. Many come from animals or plants and can be attacked by bacteria, moths and moulds. Some can be degraded or destroyed by prolonged contact with the air. Textile conservators understand these changes and try to stabilise the textile. They also recommend ways for owners and museum curators to slow the degradation down.

Some of the most challenging materials to look after are synthetic fibres like PVC, Nylon™ and polyester, which have been developed in the last 80 years. We think of these materials as lasting forever, but they do not. They break down after a period of time. However, as these materials have only been in existence for a short time, the first articles that were made from them are only now beginning to break down. This means that the chemistry of how these materials break down is far less well understood than the processes by which more traditional materials like linen, cotton, silk and wool degrade.

Damage

Textile damage can occur in a wide variety of ways. Some of the causes of this damage are things that seem harmless at first.

Water

The amount of water in the atmosphere can have a huge impact on textiles, particularly those of natural origin. Most fibres, particularly natural ones, already contain water but if there is a lot in the atmosphere they absorb even more.

1. What effect would a damp atmosphere have on the weight of a textile?

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2. If something made of delicate fibres is hanging up in a damp atmosphere, what might happen to the fibres?

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If the air around the textile is warm as well as damp then moulds can grow on it. These moulds can stain the textile and ugly marks can appear that are sometimes impossible to remove. A mould is made of a number of thread-like structures called hyphae. These hyphae eat away at the textile as they grow through it and the damage can be very severe if it is not discovered quickly.

A very dry atmosphere is not the answer either as this can cause the textile to release the water from its fibres, which leaves them dry and brittle.

Many museums with textile collections have humidity meters inside the glass display cases.

Temperature

3. If you heat an object up, what happens to the size of it? What happens when it cools?

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Textiles change in the same way as other objects when the temperature rises and falls. The structure of textiles can mean that this behaviour has a more devastating effect on them than on other things.

Textiles are usually woven. The fibres are very close together. They move as the temperature changes and rub against each other. Eventually this rubbing can wear them out so that they fall to pieces.

A rise in temperature can also cause the textile to dry out.

It is important to control the environment of textiles in a museum. Most museums try to maintain a moderate temperature (often about 18 °C) and a relative humidity of about 55%.

Dust

Dust can do a great deal of damage to textiles. Dust is made of things like grains of sand, pollutant particles, skin cells and bits of clothing that have flaked off museum visitors. It can get in between the fibres of the textile and cause a huge amount of damage by abrasion of the surface, particularly if there is also a temperature change. This is a bit like what happens if you rub your fingers with sandpaper – the skin flakes off and severe damage can result if you keep rubbing for too long.

4. Explain why the combination of a change in temperature and the presence of dust is worse than either one of these factors on its own.

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Light

Light is a problem for the textile itself but it mainly damages the dyes used to decorate the textile. In order for us to see a particular colour, a dye must absorb some parts of the visible electromagnetic spectrum and reflect back others. When light is absorbed, energy is absorbed by the textile. This can cause bonds to break and so damage the structure of the material. This occurs mainly in the dyes and can cause them to change colour.

Several hundred years ago it was common practice for people to hang large tapestries on their walls to help keep their rooms warm. Many of these tapestries now look rather odd because the dyes in them have faded at different rates. It is quite common to see blue fields in old tapestries. These fields were originally green. The green dye was made by mixing blue and yellow dyes together but yellow fades faster than most other colours so blue fields were left behind as the tapestry aged.

Many people look at old tapestries and admire the lovely, muted colours. However, these colours are often the result of fading. Sometimes you can see the original, bright colours in folds or pockets or on the back of old tapestries where light could not reach the dyes.

Other causes of damage

Textiles can also be damaged by a variety of living things. Moths and silverfish enjoy eating textiles, carpet beetles munch on anything containing wool and rats, mice and other small animals both eat textiles and take pieces away to use in their nests. Many of these animals prefer textiles which have human residues on them such as sweat and oils from the skin.

Touching objects can damage them both by abrasion and because oils and secretions from the skin are often acidic. Frequent touching can cause a huge amount of damage as can handling and moving an object – even if gloves are used.

5. Explain why textiles in museums are often displayed in glass cases in rooms with low light levels.

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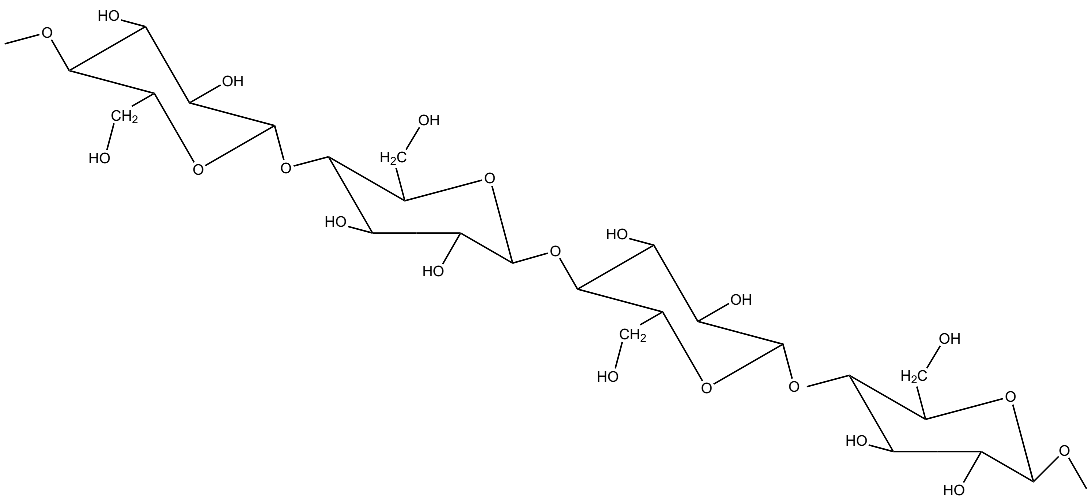
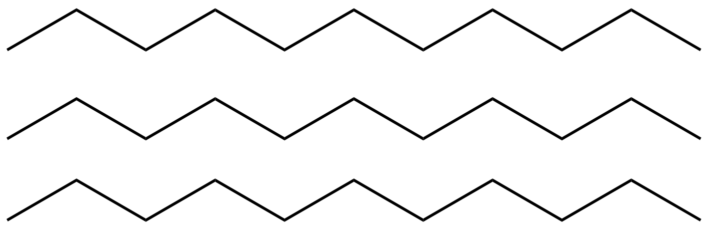
Textile conservation –
the structure of cotton and linen

Many fibres that come from plants (like linen and cotton) are formed from the polymer cellulose. Cellulose is similar to starch – both are polymers of glucose units. However, starch molecules can have branched chains whilst cellulose only contains straight chains of glucose units.

1. Look at the diagram of the structure of cellulose. Circle the repeating unit of the polymer.



In order to form a fibre, a polymer must be able to form long, ordered chains and the chains must be able to line up like this:



If the chains cannot line up they cannot form a fibre. As the molecules in the fibre are very ordered we say the substance is crystalline. Fibres may look different from crystals of salt (for example) but they are just very long, thin crystals.

2. Why is starch unable to form fibres?

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Along the cellulose fibre there are several OH groups. These groups have two important functions in the polymer fibre. They bond weakly to each other, which holds the polymer molecules together in the pattern shown above, and they also hold on to water molecules. Linen and cotton fibres contain quite a large amount of water. The water acts a little bit like a plasticiser – it lubricates the polymer chains so that they can move past each other more easily, which helps to keep the structure flexible. If some of the water is lost, more bonds form between the polymer chains. This makes the structure more like a network.

3. What would happen to the properties of linen if the water was removed from its polymer structure?

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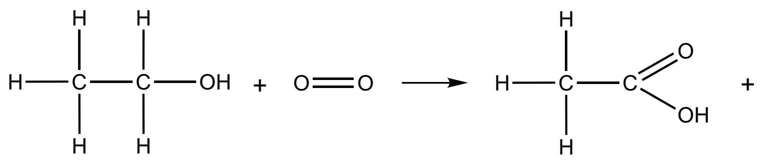
The polymer fibres can also be damaged by contact with oxygen over a long period of time. This might seem strange because we think of oxygen as vital to life (which it is) but it is an extremely reactive gas and can do a huge amount of damage to these natural fibres. The OH groups on the cellulose polymer are called alcohol groups. They react with oxygen in the same way as an ethanol molecule does, even though the fibre is a much larger molecule than ethanol. (The reaction of ethanol with oxygen results in wine turning into vinegar.)

4. Complete the equation below.



5. What type of reaction is this?

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6. What is the name of the organic molecule made in the reaction above?

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7. What functional group does this molecule contain?

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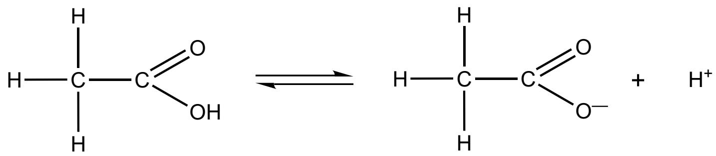
When this group is in water it dissociates and forms a hydrogen ion (H^+):



8. What do we call solutions that contain hydrogen ions?

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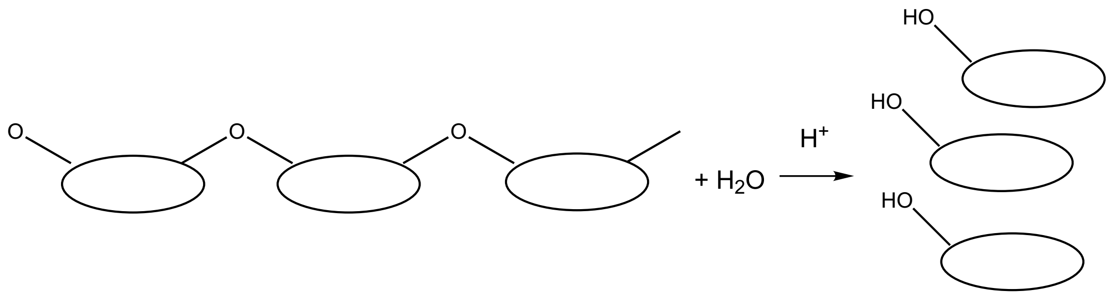
The positive ions can catalyse the breakdown of the polymer chain into monomers. A simplified equation to represent this process is shown below.

This is called a hydrolysis reaction (hydro means water; lysis means breaking).



9. What effect will the presence of the H^+ ions have on the rate of this reaction?

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10. The H^+ ions can do more damage by catalysing this reaction than they would if they simply reacted with the textile. Why is this?

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11. What effect will this reaction have on the properties of the textile?

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If nothing is done, the positive ions will go on to do further damage to the structure of the textile and it can become necessary to remove them.

12. What type of substance would react with and remove the H^+ ions from the textile?

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One way to remove these ions (and other small substances) is to clean the textile with water and detergents. Detergents fall into three main groups: cationic (positively charged), anionic (negatively charged) and neutral. Conservators usually use only anionic and neutral detergents to clean these types of fabrics.

13. Look back at the equations shown in questions 4 and 8. Explain why conservators use anionic or neutral detergents, but not cationic ones.

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H^+ ions can also be removed by washing the textile in hard water. Hard water contains Ca^{2+} and Mg^{2+} ions. These displace the H^+ ions from the fabric so that they can be washed away. This is only a temporary solution but it works well.

14. Why is this only a temporary solution?

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Another method involves using ammonia gas. This is a useful method if you do not want to get the fabric wet – for example, any dyes in it might run. The ammonia reacts with the acid groups in the fibres.

15. Complete the equation shown below.

$$H^+ + NH_3 \rightleftharpoons$$

16. This is also only a temporary solution. Explain why.

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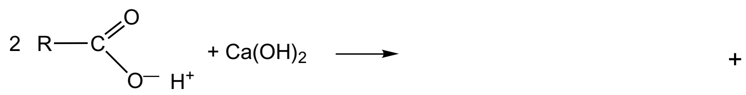
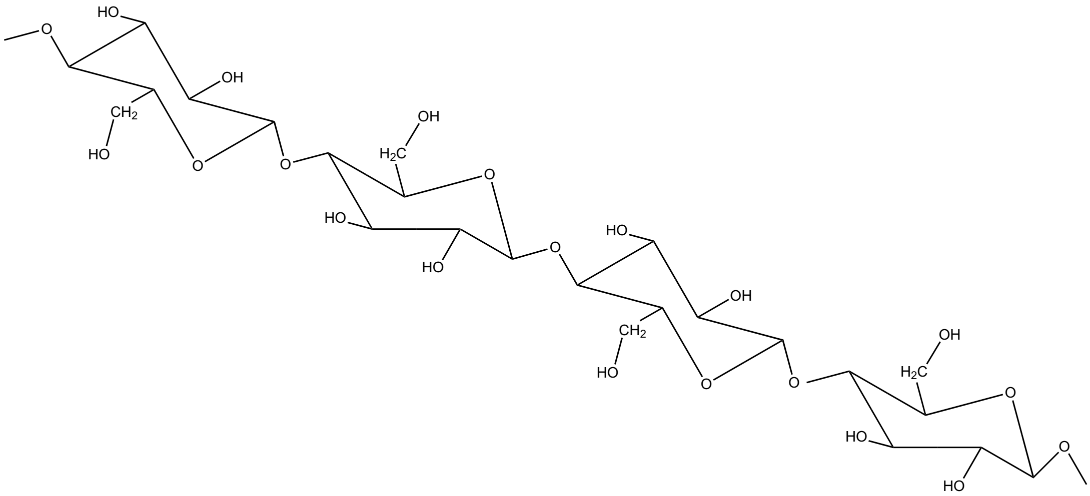
In the future, conservators may be able to treat textiles with nanoparticles of calcium hydroxide, $Ca(OH)_2$. This is not yet a routine treatment but research is being carried out to see if it has potential for future use.

17. Complete the equation below to show how calcium hydroxide particles would react with the damaged textile.



Textile conservation – structure of cotton and linen

The diagram below shows the structure of cellulose.



Textile conservation case study – the Victory sail

In 1805 HMS Victory was the flagship of Admiral Nelson's fleet as he led the Navy to victory in the Battle of Trafalgar.

BHC3696 National Maritime Museum The 'Victory' leaving the Channel in 1793 by Monamy Swaine c. 1795

The ship had many sails but only one of them has survived. It was badly damaged during the battle and has many holes in it from cannon balls and other gun fire. This extensive damage is probably the reason the sail has survived – the other sails were almost certainly cut up and re-used in other ships. Not only is this sail the only surviving one from HMS Victory, it is probably the only remaining sail from the entire fleet.

A picture does not really get across the enormous size of the sail. It is 24 m x 17 m and weighs over half a tonne. It would have been made by hand by experienced sail makers and probably took about 1200 man hours to stitch. It is made of linen, which is a cellulose fibre that comes from the flax plant.

The sail has not always received the treatment and respect that might be expected for such an important relic. It was made in 1803 and went into service on HMS Victory. It remained on HMS Victory until the ship returned for repairs after the Battle of Trafalgar in 1806. What happened to the sail over the next 85 years is not really known. It was displayed at an exhibition in 1891 and was on board HMS Victory for the centenary celebrations of the Battle of Trafalgar in 1905. In 1960 it was discovered in a sail loft in the Navy barracks covered in gym mats. It was returned to the ship to be displayed in a glass cabinet in 1962 then left the ship for good in 1993, when it was found that the sail was deteriorating rapidly and needed urgent conservation work.

The sail was first carefully inspected and documented. Several photographs were taken, along with video footage. The whole sail was mapped and diagrams were drawn. These records will help future historians and conservationists know what was done to the sail at this time.

The conservators need to understand the chemistry of the linen the sail is made of so that they can decide how best to assess and treat it.

After the documentation, the sail was thoroughly vacuumed.

Some fabrics can be washed to remove problem substances like acids, which are formed by the breakdown of the polymer chains that make up the fibres of the fabric. However, washing causes a lot of damage to very old linen so it is not a possible treatment for the Victory sail.

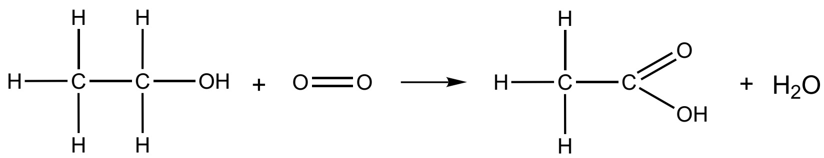
Conservators do not have to rely only on the observations they can make by eye to decide how best to treat an object. As part of the celebrations of the bicentenary of the Battle of Trafalgar, the Navy would have liked to hang the Victory sail in public view once more. However, they did not wish to damage it further so they needed to find out whether the fabric was strong enough to hold its own weight. They did not want it to break when they hung it up. They needed to test the fibres – but if they did so they could have damaged the sail. This is a problem with many objects that conservators work on.

Dr Paul Wyeth and Dr Paul Garside at the Textile Conservation Centre in Winchester have been working on this problem. They are developing ways to assess damage to fibres by using non-invasive and non-destructive tests. They are using infrared spectroscopy to look at how textiles change as they get damaged by age and wear.

Remember

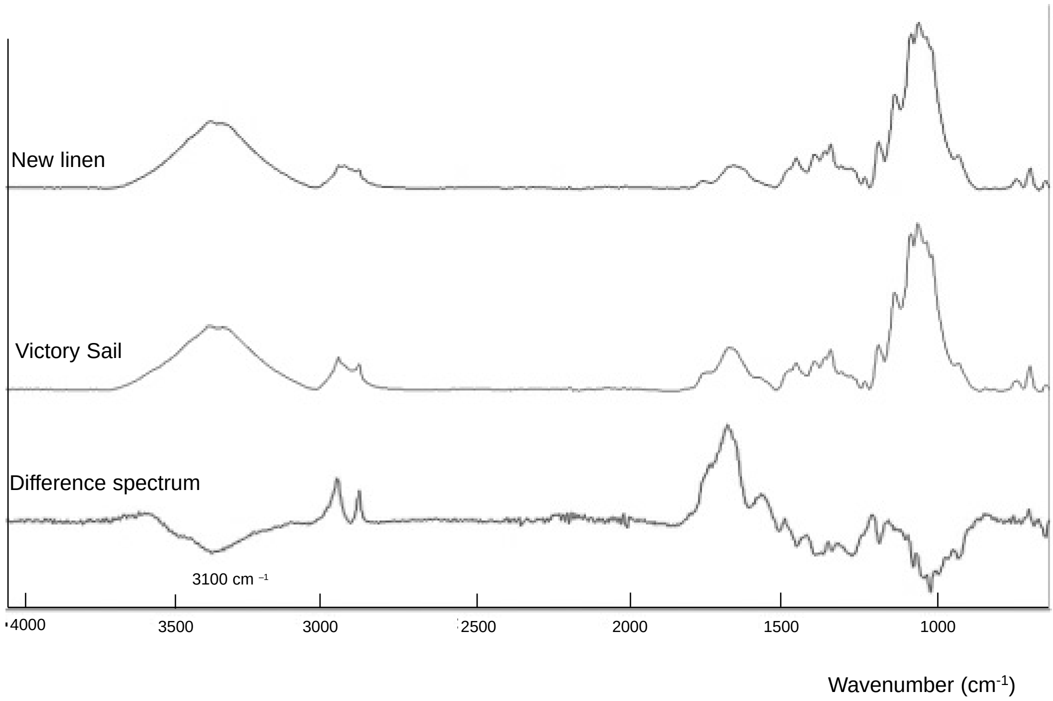
Alcohol groups in the linen structure can be oxidised by oxygen in the air to form carboxylic acid groups:

IR (infrared) spectra of new linen and the linen from the Victory sail are shown below.



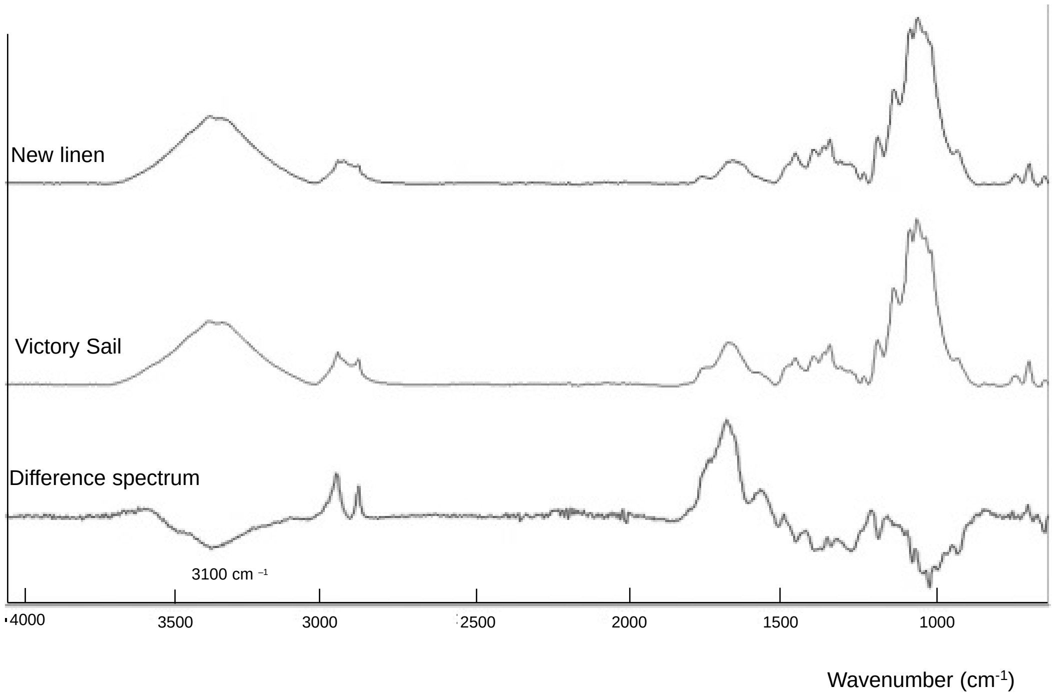
The top plot is from new linen sailcloth and the middle one is from the Victory sail linen. The bottom plot is done by a computer – it is the Victory sail spectrum minus the new linen one.

The bottom plot shows the differences between the linen from the Victory sail and new linen. By looking at this spectrum it is possible to see how the sail has changed and been damaged with time. The two bands at 2930 cm^{-1} and 2850 cm^{-1} show that the canvas has gained some oils or waxes that were not originally present in the sail.



Spectra reproduced with kind permission from P. Wyeth, Textiles Conservation Centre, Winchester Campus, Southampton University

Questions



1. Why was it important to vacuum the sail?

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2. Mark and label the bands 2850 cm^{-1} and 2930 cm^{-1} showing oils on a copy of the spectra.

The difference spectrum (the one at the bottom) has a band at 1720 cm^{-1}. This is typical of a carbonyl group, C=O.

3. Mark and label this band on the spectrum. Explain how the presence of this band supports the idea that the linen from the sail has been oxidised.

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OH groups in the linen absorb at 3100 cm^{-1}. The difference spectrum has a negative band at 3100 cm^{-1}, which shows that the number of OH groups in the Victory sail is smaller than the number in the new linen.

4. Does this band confirm that the reaction shown in the equation has occurred? Explain your answer.

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5. How can information from IR spectra like these help textile conservators to determine the extent to which linen textiles have been damaged?

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