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.

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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:

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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.

\[
\begin{align*}
\text{H}_2\text{C} & \text{C} \text{OH} + \text{O} = \text{O} \rightarrow \text{H}_2\text{C} & \text{C} \text{} \\
\text{OH} & + \text{H}_2\text{O} \\
\end{align*}
\]

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⁺):

\[
\begin{align*}
\text{H}_2\text{C} & \text{C} \text{OH} \Leftrightarrow \text{H}_2\text{C} & \text{C} \text{O}^{-} \\
& + \text{H}^+ \\
\end{align*}
\]
8. What do we call solutions that contain hydrogen ions?

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).

\[
\begin{align*}
&\text{O} & &\text{O} & &\text{O} \\
+ & & & + & & \text{H}_2\text{O} \\
& & & & & \text{H}^+ \\
\end{align*}
\]

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

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?

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

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?

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.
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?

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.

\[
\text{H}^+ + \text{NH}_3 \leftrightarrow
\]

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

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.

\[
2 \text{R}_n\text{CO}_n\text{O} \text{H}^+ + \text{Ca(OH)}_2 \rightarrow +
\]
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The diagram below shows the structure of cellulose.