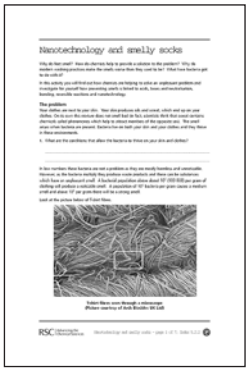
Nanotechnology and smelly socks



Index 5.2.1
1 sheet
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7 sheets

This activity is based on the science behind the consumer product 'Purista', a treatment for textiles which helps to kill the bacteria that grow on clothing and cause it to smell.

The activity requires background knowledge of a number of areas of science:

- Bacteria
- Acids/bases and neutralisation
- Reversible reactions
- Ionic bonding.

Further information about the product is available on the company's website **http://www.purista.co.uk** (accessed November 2005) but there is very little scientific information there.

'Purista' is the marketing name of the bacteriocide PHMB or Poly(hexamethylene biguanide hydrochloride). It has long been used in swimming pools and contact lens solutions but has now been developed by Arch Chemicals to provide near-permanent antibacterial protection for clothing.

The polymer contains positive groups that appear regularly along its chain:

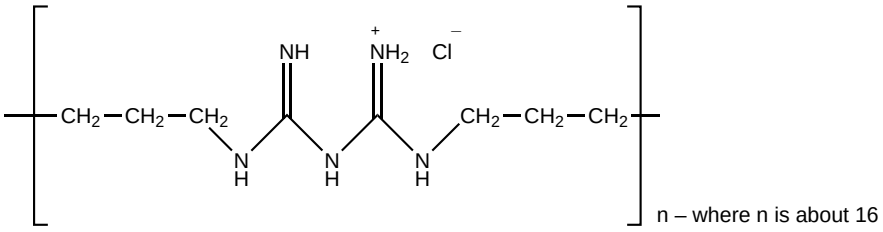

Figure 1 PHMB or Poly(hexamethylene biguanide hydrochloride)

These positive groups can bind to cellulose fibres, such as cotton or viscose. The fibres contain carboxylic acid groups formed by oxidation of alcohol groups during processing of the raw material:

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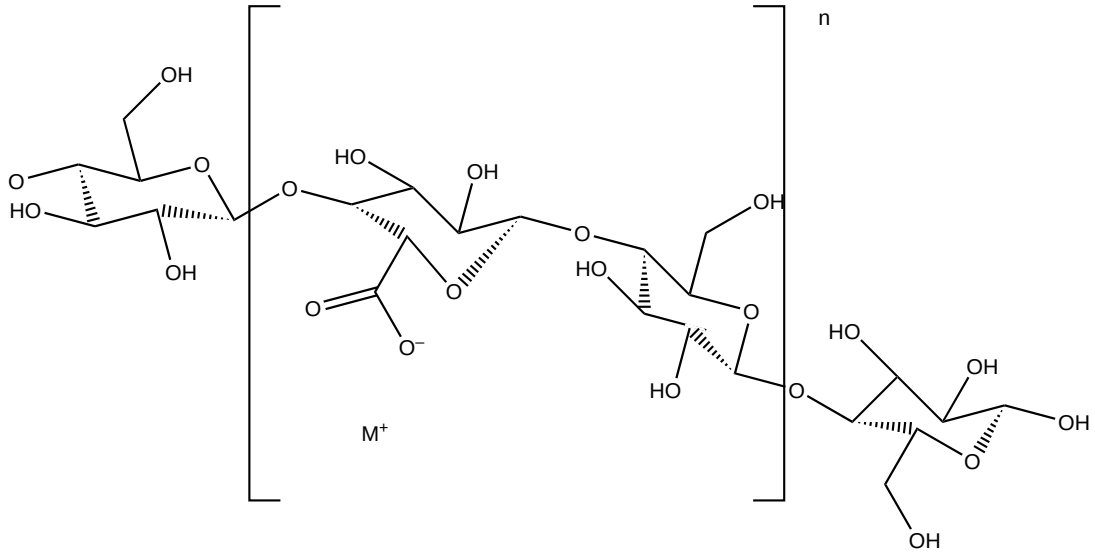

Figure 2 A cotton fibre after processing

In solutions above about pH 6, the carboxylic acid groups dissociate to give carboxylate ions, which are negatively charged. These carboxylate ions bond to the positive charges on the PHMB molecule and hold it in place. Several bonds form between each PHMB molecule and cotton fibre, which join together a little like Velcro®. This holds the PHMB in place even during washing.

No bacteria have yet been found that are resistant to PHMB, even though it has been used in swimming pools for many years.

Suggested lesson plan

- To introduce the lesson you could show the slide **Odd one out?** provided in this resource. The bacteria is the odd one out because the rest of the items contain PHMB, sometimes known as 'Purista®', which kills bacteria.
- The Belle and Bunty website (**http://www.belleandbunty.co.uk**, accessed November 2005) sometimes has a video of their latest show, which you could use as an introduction.
- Students work through the information and questions. For greater impact, you could put the pictures of bacteria up on a screen using a data projector. Some sensitivity may be required if you have students in the class who have a body odour problem.
- The material could lead to a discussion of how science is presented to the general public. Why is such a scientific product marketed without any mention of how it works? Can students think of other products where this is also the case?

Answers to questions

1. Bacteria on clothing and on your skin have warmth, food, water and shelter. These conditions allow them to thrive.

2. Washing is now largely done at 40 °C, which is not a high enough temperature to kill bacteria. Thus the bacteria can survive from one wash cycle to the next, their numbers building all the time. (They are also stuck to the clothing in a biofilm which is not broken down at 40 °C.)

3. Although the bacteria are being killed, sweat, oils and dirt still accumulate on the clothing and must be removed.

4. Delicate clothing needs to be washed at low temperatures that do not kill bacteria so Purista can help get rid of the bacteria instead. Socks are very good places for bacteria to grow because they are worn inside shoes where the bacteria are kept warm and moist and the colony can grow rapidly. Purista helps solve this problem.

5. All acids contain the H^+ ion.

6. $HCl + NaOH \rightarrow H_2O + NaCl$

7. $H^+ + OH^- \rightleftharpoons H_2O$

8. The symbol means reversible reaction/reaction at equilibrium.

9. You could ensure that there are several negative charges on the fabric by removing the H^+ ions, which would cause the equilibrium to move to the right. You could do this by adding alkali to the solution. The alkali would react with the H^+ ions and remove them.

10. The cotton fibres need several negative charges so that the PHMB can attach to the fibres in several places and be held in place more effectively.

11. An ionic bond will form between the cotton and the PHMB.

12. There are few negative charges on the cotton at low pH so it is unable to bind to the positive PHMB. Above pH 6, there are very few H^+ ions to stick to the cotton so the PHMB can stick instead. Adding an alkali removes H^+ ions, which moves the equilibrium to the right so that more negative charges are formed, providing more places for the PHMB to bind.

13 and 14. In questions 13 and 14 students are asked for their opinion.

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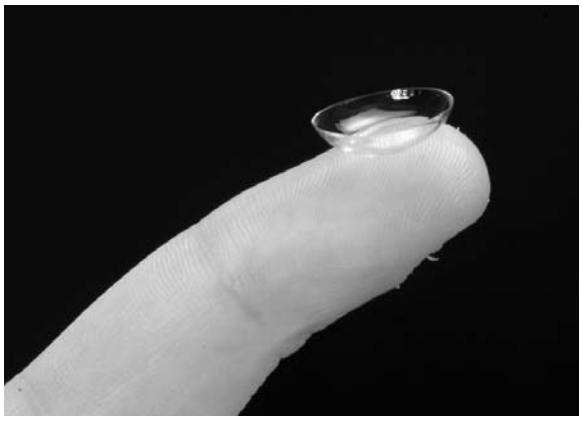
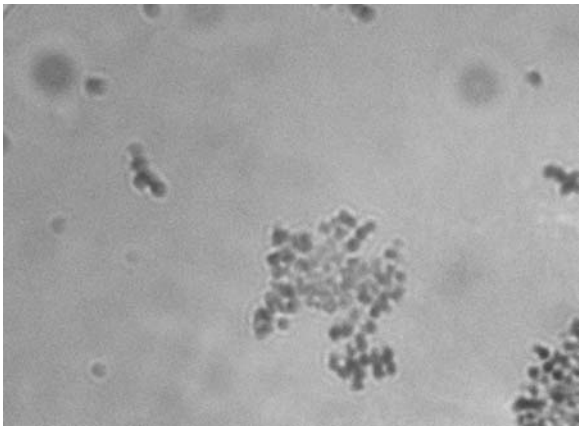
Nanotechnology and smelly socks – introduction

Which is the odd one out?

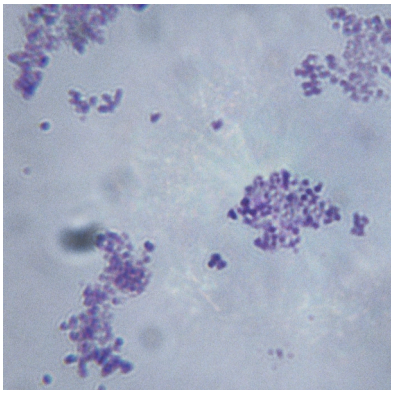
This is available as a slide on the CDROM – Index 5.2.1



Picture reproduced by kind permission of Belle & Bunty (http://www.belleandbunty.co.uk)



Odd one out?



Nanotechnology and smelly socks

Why do feet smell? How do chemists help to provide a solution to the problem? Why do modern washing practices make the smells worse than they used to be? What have bacteria got to do with it?

In this activity you will find out how chemists are helping to solve an unpleasant problem and investigate for yourself how preventing smells is linked to acids, bases and neutralisation, bonding, reversible reactions and nanotechnology.

The problem

Your clothes are next to your skin. Your skin produces oils and sweat, which end up on your clothes. On its own this mixture does not smell bad (in fact, scientists think that sweat contains chemicals called pheromones which help to attract members of the opposite sex). The smell arises when bacteria are present. Bacteria live on both your skin and your clothes and they thrive in these environments.

1. What are the conditions that allow the bacteria to thrive on your skin and clothes?

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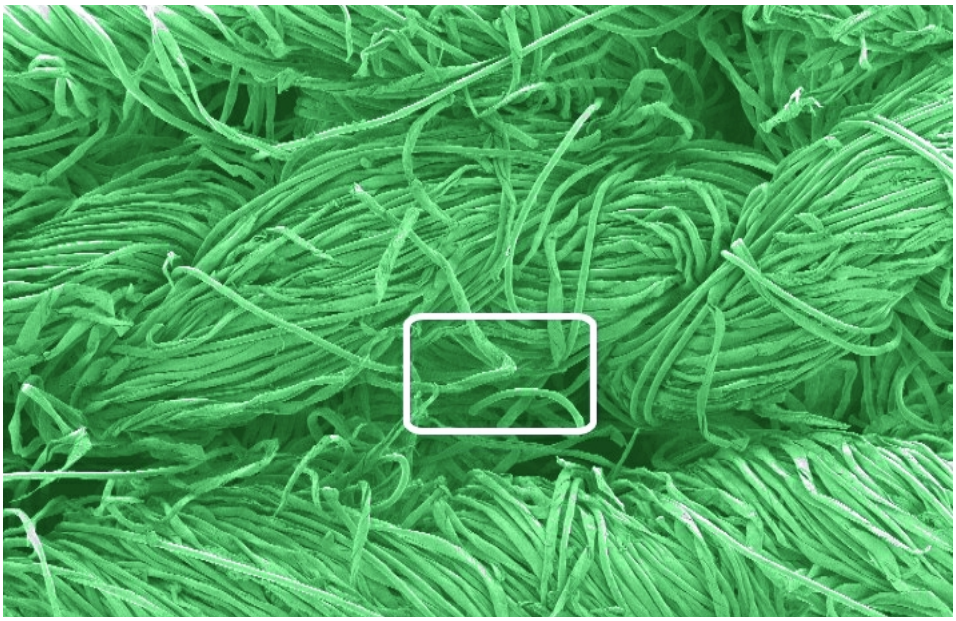
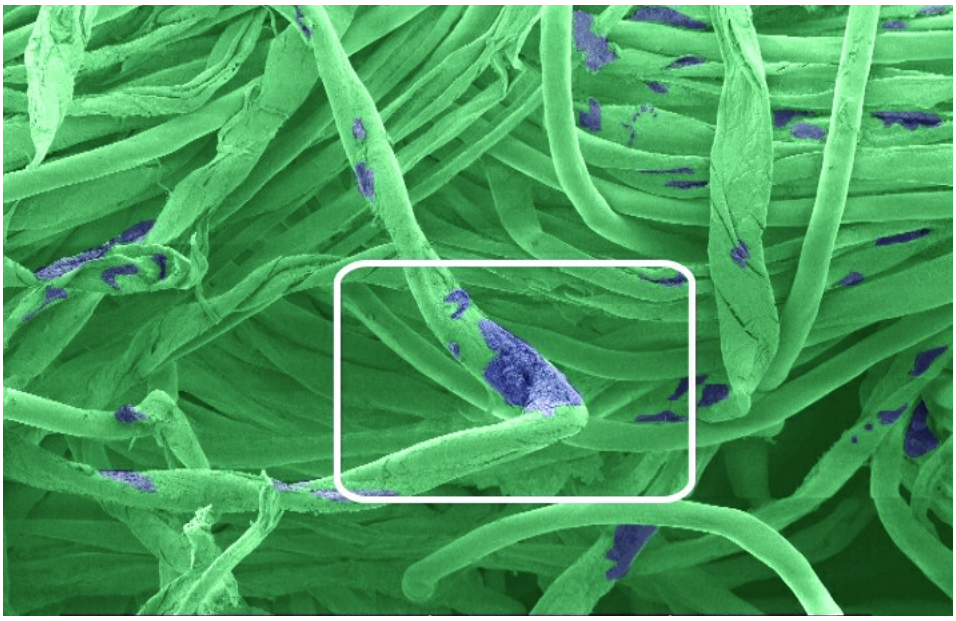
In low numbers these bacteria are not a problem as they are mostly harmless and unnoticable. However, as the bacteria multiply they produce waste products and these can be substances which have an unpleasant smell. A bacterial population above about 10^5 (100 000) per gram of clothing will produce a noticable smell. A population of 10^6 bacteria per gram causes a medium smell and above 10^8 per gram there will be a strong smell.

Look at the picture below of T-shirt fibres.



T-shirt fibres seen through a microscope
(Picture courtesy of Arch Biocides UK Ltd)

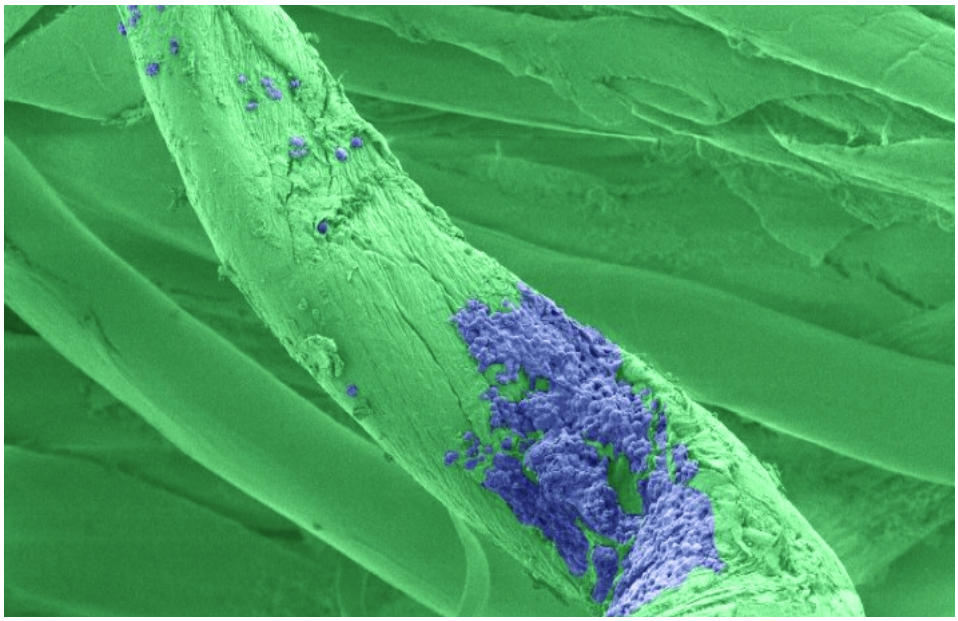
Now look more closely:



T-shirt fibres magnified even more
(Picture courtesy of Arch Biocides UK Ltd)

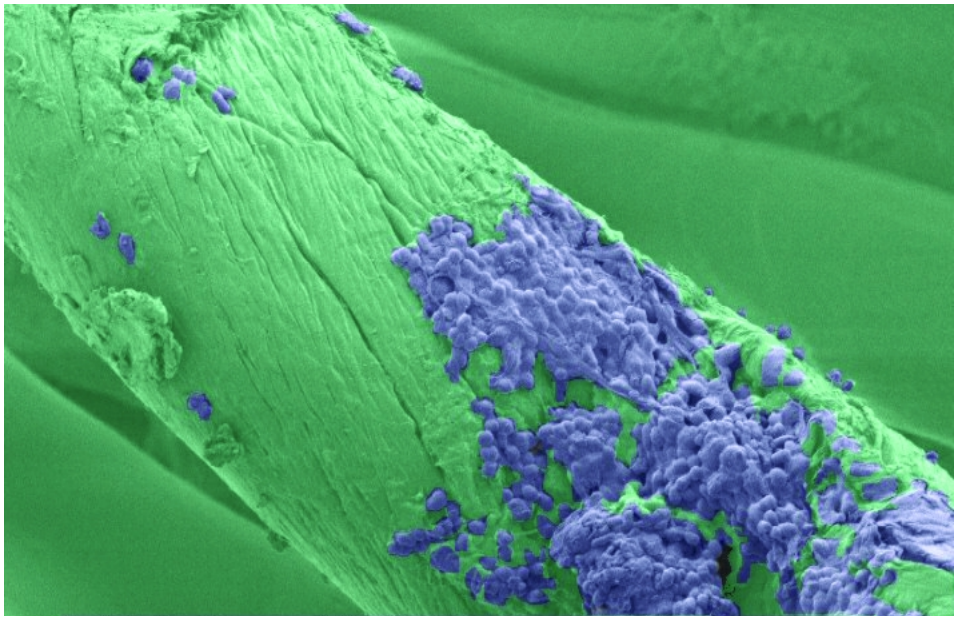
If you look at the middle of the photograph above, you can see that there seems to be some damage to the fibre. This is not visible to the naked eye.

Look at the fibre in close-up:



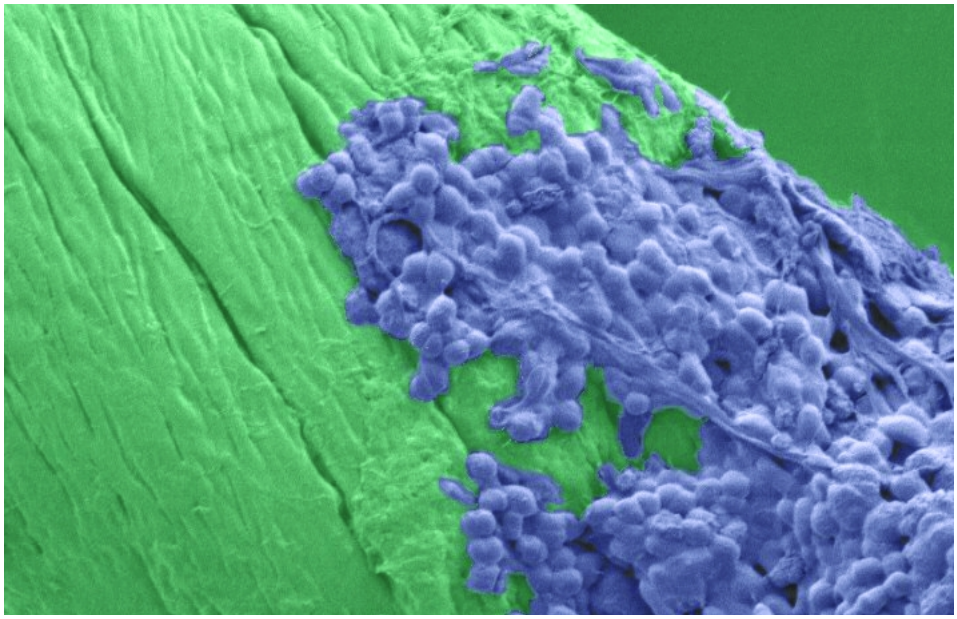
T-shirt fibre in close-up
(Picture courtesy of Arch Biocides UK Ltd)

It is still hard to tell what the damage is caused by. The next photograph should help:



Bacteria in a biofilm on a t-shirt fibre
(Picture courtesy of Arch Biocides UK Ltd)

A colony of bacteria is living on the t-shirt fibre. The bacteria glue themselves to it and form a 'biofilm.' This biofilm is very difficult to remove and can remain even after washing.



Modern washing practices have not helped this problem. A few years ago it was common to wash many items on a hot wash (60 °C or above). Now, most clothing is washed on a cool cycle at 40 °C and many new fabrics cannot be washed above this temperature.

2. Why do modern washing practices help bacteria?

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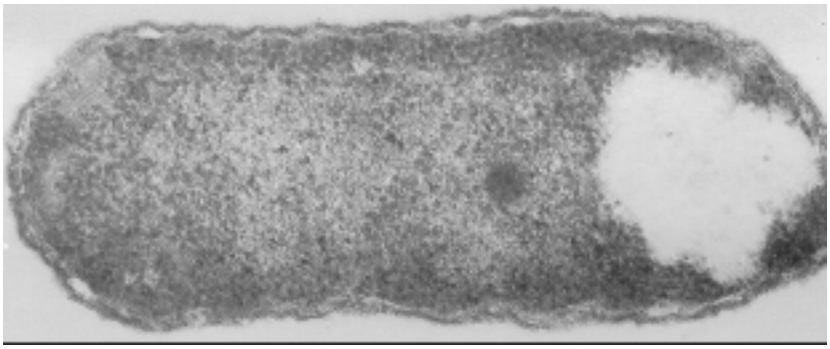
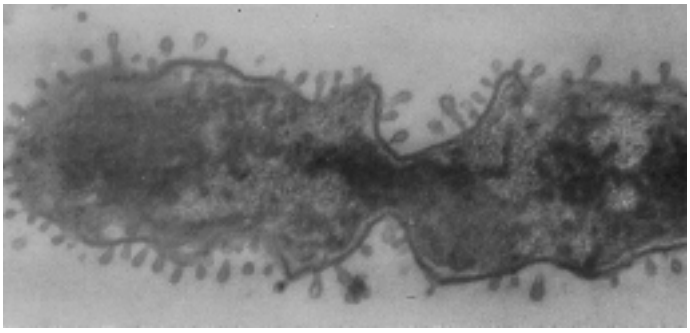
Scientists at Arch Chemicals have been working on a solution to this problem for a number of years. They have designed a product that manufacturers can apply to clothing to help prevent bacterial growth. This product is a chemical called PHMB and has been used in swimming pools and contact lens solutions for several years. It kills bacteria by puncturing their cell membranes, causing the contents to leak out. It does not have the same effect on human cells so it is safe to use in contact with the skin.



A bacterium before treatment with PHMB
(Picture courtesy of Arch Biocides UK Ltd)



A bacterium after treatment with PHMB
(Picture courtesy of Arch Biocides UK Ltd)

Once the bacteria are dead they can no longer produce smelly chemicals and the fabrics smell fresh for longer. They still need to be washed, but perhaps not as often.

3. Why do the fabrics still need to be washed?

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PHMB is given the trade name 'Purista®.' It is used by a number of manufacturers of socks and also by the designers Belle and Bunty. Their clothes are made of very delicate fabrics and cannot tolerate harsh washing conditions.

4. Why would the product 'Purista®' be particularly useful for socks and for delicate, expensive clothing?

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The fabric

Cotton fibres are made of cellulose, which is a polymer of glucose and is similar to starch. When the fibres are processed some of the cellulose is oxidised and the product is slightly acidic.

5. Which ion do all acids contain?

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6. Write an equation for the reaction between hydrochloric acid (HCl) and the alkali sodium hydroxide (NaOH).

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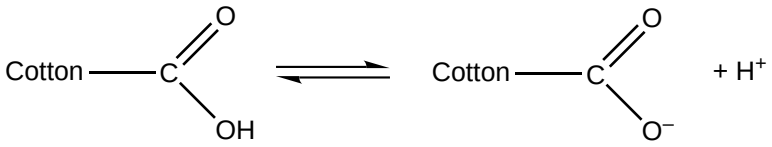
7. Write an equation for the reaction between any acid and any alkali.

Part of the cotton fibre is an acid. The fibre can lose an H^+ ion leaving a negative charge on the remaining fibre:



For the Purista® treatment to stick to the cotton fibres it is important that there are several negative charges on each fibre.

8. What does the ⇌ symbol in the equation above mean?

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9. How could you ensure that there are several negative charges on the cotton fibres?

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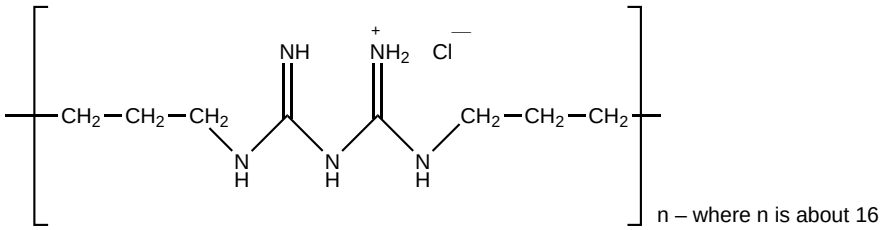
The treatment

The substance used to treat the cotton is also a polymer. Its chemical name is PHMB, which stands for poly(hexamethylene biguanide hydrochloride).



PHMB

Each molecule of PHMB contains about 16 of the repeating units shown in the diagram.

10. Why is it important for the cotton fibres to have several negative charges?

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11. What type of bond will form between the cotton fibre and the PHMB?

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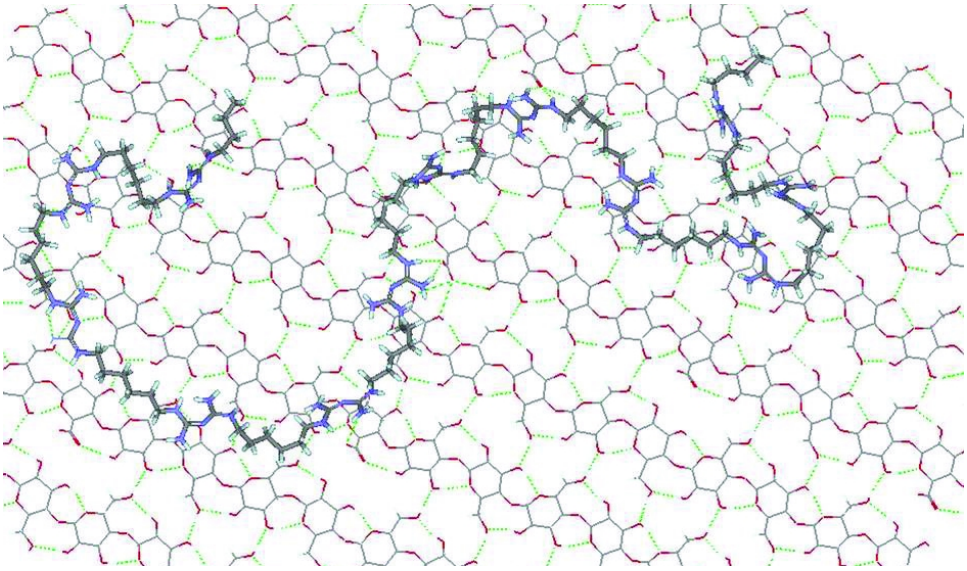
The PHMB winds along the cotton like a snake and bonds at several places along its length like velcro®. This helps the PHMB to lie flat on the surface of the cotton. The coating on the surface is no more than a few nanometers thick, which makes this an example of nanotechnology. The bonds are strong enough to hold the PHMB on the cloth even during washing.



PHMB lies flat on the cotton surface and multiple attractions between the PHMB and the cotton fibres give a velcro® effect

Arch chemicals supply PHMB to textile manufacturers with the following information:

> *The ability of cotton to absorb PHMB is governed by the pH of the PHMB solution. If the solution is below pH 5, the PHMB is unable to bind to the cotton fibres. Above pH 6, strong binding occurs. Aqueous solutions of PHMB must be adjusted to a pH of above 6 before use. Sodium hydroxide or sodium carbonate can be used to raise the pH.*

12. Explain, as fully as you can, why this advice is given.

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Marketing

When this product is marketed to the consumer the name 'Purista®' is used instead of PHMB. It is used for a variety of products from socks to sheets and even designer dresses. You may have seen the logo in the shops:

Purista logo

13. Why do you think the phrase 'fresher for longer' is used rather than, say, 'kills the bacteria that make you smell'?

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14. Why do you think the product is marketed as Purista® rather than PHMB or poly(hexamethylene biguanide hydrochloride)?

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Something to think about

The Purista® logo and the information provided to the public about Purista® avoids any mention of science – either biology or chemistry.

- Why do you think this is?
- How would you market this product?
- Can you think of other products that are based on science but whose marketing does not mention it?
- Which products are marketed with information about the science on which they are based?
- What is the difference between the products for which science is mentioned and those for which it is not?