Science Enhancement Programme

FIBRES AND FABRICS

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The Science Enhancement Programme is a part of Gatsby Technical Education Projects. It is developing curriculum resources to support effective learning in science, and providing courses and professional development opportunities for science teachers. This booklet is part of the series 'Innovations in practical work', exploring ways in which low-cost and novel resources can be used in secondary science.

Science Enhancement Programme

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HEALTH AND SAFETY

For practical activities, the Science Enhancement Programme has tried to ensure that the experiments are healthy and safe to use in schools and colleges, and that any recognised hazards have been indicated together with appropriate control measures (safety precautions). It is assumed that these experiments will be undertaken in suitable laboratories or work areas and that good laboratory practices will be observed. Teachers should consult their employers' risk assessments for each practical before use, and consider whether any modification is necessary for the particular circumstances of their own class/school. If necessary, CLEAPSS members can obtain further advice by contacting the Helpline on 01895 251496 or e-mail science@cleapss.org.uk.

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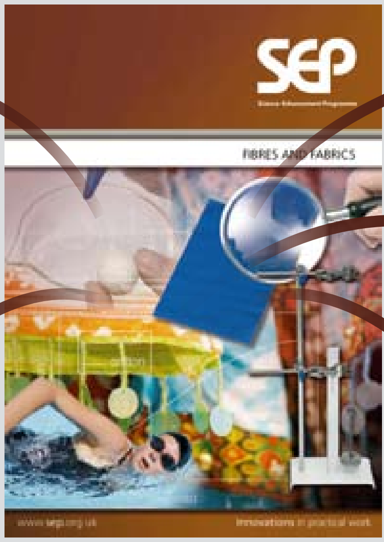

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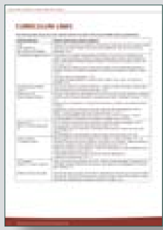

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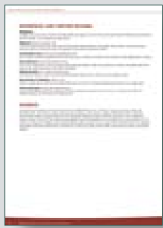

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INTRODUCTION

Fabrics have diverse uses from medical gauzes and summer gazebos to the most obvious use, clothing. New applications for traditional fabrics are being found, but increasingly, fibres and fabrics are engineered for specific purposes. There is a lot of research currently being undertaken in the textile sector to design new fibres, fabrics and threads with carefully controlled properties to meet the needs of niche markets such as competitive sports wear, or specialist applications such as spacesuits. The advent of smart materials and fabrics has generated a renewed interest in this area of science.

'Fibres and Fabrics' encourages students to test and research the properties of different threads, fabrics and dyes with a clear link to the new 'How Science Works' curriculum. Knowing the properties of fabrics and dyes can help students make informed decisions about the clothes that they wear. In addition to student practical activities, there are also some teacher demonstrations and student research activities drawing on secondary sources of information.

The activities are designed to support the requirements of GCSE science specifications, but could be adapted for younger students. A range of low-cost practical resources to support the activities are available for purchase from Middlesex University Teaching Resources (MUTR).

CURRICULUM LINKS

The following table shows the main relevant sections for each of the current GCSE science specifications.

GCSE specification	Sections particularly related to polymers
AQA Unit Chemistry 1b Oils, Earth and Atmosphere	Polymers have properties that depend on what they are made from and the conditions under which they are made. Polymers have many useful applications and new ones are being developed. (12.4)
AQA Additional Applied Science	Describe how to avoid the contamination of evidence at a crime scene. Describe how to collect and record samples of forensic samples including fibres. Describe distinct features of fibres. State whether observable features indicate a link between the suspect and the scene of a crime. (11.3) Give examples of materials used to make sports clothing. Give characteristic properties of polymers. Describe how different properties of materials are desirable for different clothing. (11.4) Carry out a forensic investigation. (12.3) Investigate the appropriateness of materials that could be used in sport for a particular purpose. (12.4)
AQA Engineering (Double award)	Learn about and look at samples of polymers, composite, textile technology, including liquid crystal coated fabrics and thermochromic dyes. (10.2)
Edexcel Unit C1 b Topic 8 Designer Products	Use given information to relate properties to some of the uses of smart materials in clothing, extreme sports and sports equipment, including carbon fibres, Thinsulate™ and Lycra™. (C1b 8.1) Explain that smart materials can change their properties in response to an external stimulus. (C1b 8.2) Explore how scientists sometimes create new materials with novel properties, such as Teflon™, where the applications only emerge afterwards. (C1b 8.3) Explain the breathability of fabrics like Gortex™ in terms of their structure. (C1b 8.4) Use the properties of materials such as Kevlar™ to suggest uses. (C1b 8.5)
Edexcel Unit C3 Topic 4 Chemistry Working for Us	Use of transition metals and their compounds as catalysts, pigments and dyes. (C 34.1) The preparation of soap from fatty acids and an alkali. (C3 4.16) The detergent action of surfactants in lowering surface tension to remove dirt and or oil/grease. (C3 4.17) The advantages of using detergents instead of soap in hard water areas. (C3 4.19)
OCR 21st Century C2 Material Choices	Relate properties to the uses of materials such as plastics, rubbers and fibres. (C2.1, 2) Interpret information about the properties of materials such as plastics, rubbers and fibres to assess the suitability of these materials for particular purposes. (C2.1, 4) Recall that materials can be obtained or made from living things, and give examples such as cotton, paper, silk and wool. (C2.2, 2) Understand that there are synthetic materials which are alternatives to materials from living things. (C2.2, 3)
OCR Gateway Module C1 Carbon Chemistry Module C2 Rocks and metals	State uses to show how polymers are used in clothing. State advantages of waterproof and breathable clothing. Describe the construction and relate this to the properties of Gore-Tex® type clothing. (C1f) Describe that dyes are used to colour fabrics. Describe that some dyes are natural and others are synthetic. Describe that thermochromic pigments change colour when heated or cooled. Describe that phosphorescent pigments can glow in the dark. (C2a)

FIBRES AND FABRICS IN THE CLASSROOM: IDEAS AND SUGGESTIONS

Fabrics are materials made from weaving, knitting, crocheting or felting fibres together. The fibres can be obtained from natural sources or they may be made synthetically. Often the fibres are spun or wound together to form a thread before being made into a fabric. The nature of a fabric will depend on the fibres from which it is made and the way that they are arranged, and its properties will determine the applications for which it is suitable. The properties of fibres and fabrics can also be modified by treating them, for example, by dyeing or by waterproofing.

This section gives an 'illustrated overview' of how practical work on fibres and fabrics can be undertaken in the classroom. In the margin, references are given to student activities – these resources and the accompanying teachers' notes can be found later in the booklet.

FIBRES, THREADS AND FABRICS

Natural fibres can be obtained directly from a plant or an animal. Plant fibres are usually made of cellulose, a natural polymer chain that forms a long string or fibre within the plant. The raw fibres can be harvested, and then refined and twisted together to make a thread. These threads can then be worked to make fabrics.

Cotton fibres obtained from the plant can be spun together to make threads, which are woven together to make a fabric.

Animal fibres are composed mainly of proteins and are usually obtained from the fur of mammals: mainly from sheep but also from lamas, goats and rabbits. Wool is different to normal mammalian fur because it is crimped (it has bends down the fibre) and it is elastic. To make wool, the animal is shaved, and the fleece is washed (scoured) to remove dirt and natural oils. It is then carefully combed and spun to produce threads. Another important source of animal fibres is the silkworm. The long silk fibres can be unwound from the cocoons and spun together to make a thread. The silk thread is then woven to make silk fabric.

A silk cocoon, silk thread and silk fabric.

Synthetic fibres, such as nylon and polyester, are manufactured by chemically reacting materials that are mainly derived from crude oil. Like natural fibres they can be combined together to form threads and woven into fabrics. They can also be made in a sheet form such as the Teflon layer inside waterproof clothing.

Rayon is made from natural cellulose fibres that have been broken down chemically and then regenerated. Therefore, it is difficult to classify this material as either synthetic or natural, and it is often classified as a 'manufactured fibre'. Rayon's properties are similar to silk, although as it ages it tends to turn yellow and 'pill' (make bobbles on the surface). The DuPont chemical company began to make the material commercially in the 1920s and marketed it as a cheaper alternative to silk, known as 'art silk', where 'art' was short for 'artificial'.

Most fabrics are produced from fibres that have been combined to form threads, which have then been woven or knitted together. Fabrics can also be made directly from fibres by felting. In this process the fibres are randomly pushed together so that they tangle and make a matted sheet. As natural fibres are not uniform, they have a rough edge and so they are easily felted.

The properties of a fabric may be different to the properties of the fibres or the threads from which it is made. For example, nylon thread is itself waterproof, but when woven, the fabric may have holes that make it permeable to water. Also the process by which a fabric is formed from threads can lead to different properties. For example, a fabric made from woven threads has a higher SPF (sun protection factor) than from the same threads crocheted, due to the size of the holes between threads.

EXAMINATION AND IDENTIFICATION

Different fibres have distinctive appearances, and this is of great importance in forensic work. Fibres are often left at a crime scene; they may be in the form of single fibres, a thread or even a piece of fabric. Collection and identification of this evidence can be used in prosecutions. The role of a SOCO (Scenes of Crime Officer) is to collect uncontaminated evidence carefully from a crime scene. The specially trained officers may be able to identify the fabric, or match it to a suspect's clothing by looking at it under a microscope. Sometimes, there may be evidence trapped in the fabric, such as pollen spores, that could be used to distinguish samples of fabrics even if they came from the same original source.

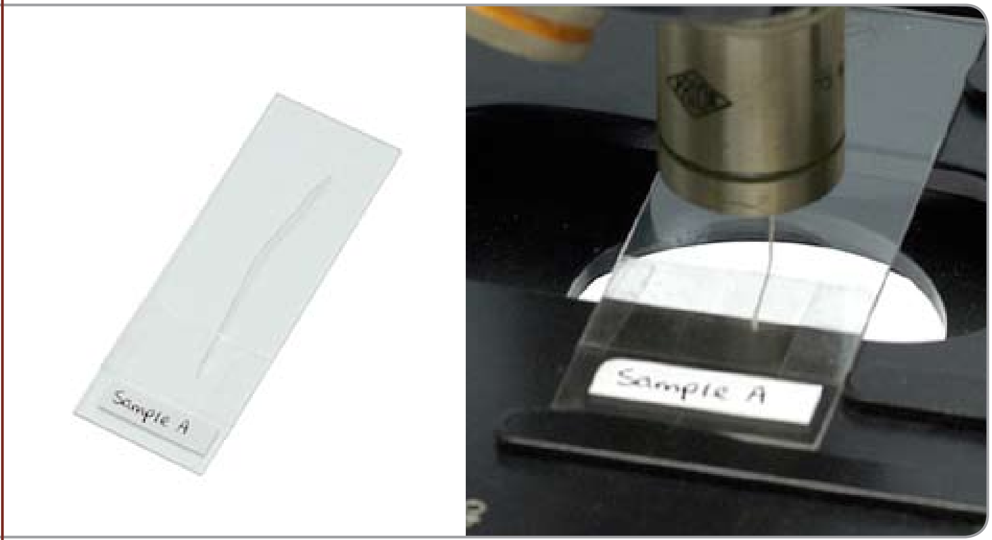
When handling forensic evidence it is essential to ensure that it does not become contaminated with additional fibres.

The Forensic Science Service has special microscopes that have two stages, so that two samples can be viewed simultaneously. This allows them to be easily compared. The technician will be looking to see whether the textures are the same or different; in addition, if a piece of fabric has been torn, matching the edges of two pieces can prove that they were originally from the same piece of cloth.

Classroom activities

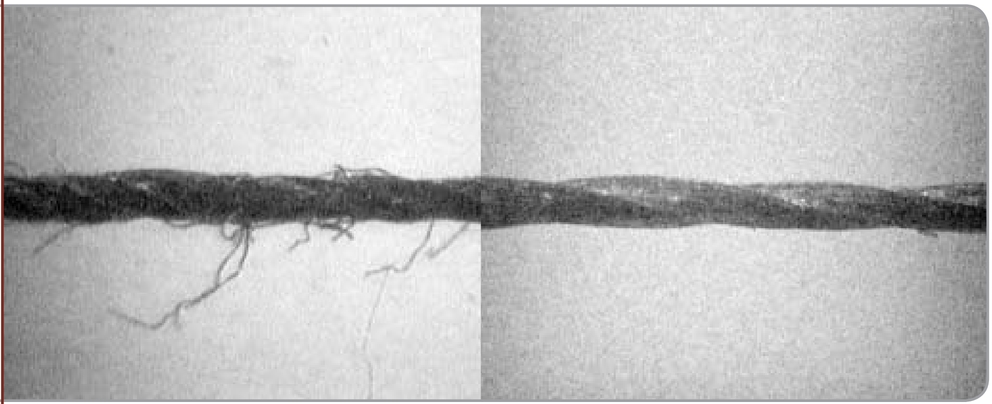
See Activity A1
Collection and microscopic analysis of threads
(page 28)

Students can examine samples of commercially available threads (for example, cotton, nylon, polyester, silk) and identify them by comparison with known samples or with microscopic images. By using the naked eye, it is difficult to appreciate how threads of different materials vary. However, even with low magnification, students can see how varied the physical structure of threads can be.



A thread is mounted on a microscope slide and magnified; it can be compared to specimen images to identify the thread.

Often synthetic threads are smooth, whereas natural threads may have 'fibres' bursting from them. Synthetic threads are made by extruding long fibres, which are then twisted and sometimes bonded together; natural fibres however, tend to be shorter.



Natural threads such as cotton (left) often have a fuzzy appearance, whereas synthetic threads such as nylon (right) tend to be smoother. (Shown here at 20x magnification.)

It is important for students to understand the distinction between fibres and fabrics. Fibres can have properties that the fabric does not and vice versa. This means that the microscopic properties of the fibre can be different to the macroscopic properties of the fabric. Students can examine different samples of fabric with a hand lens and observe the differences between the way the threads are woven together. Magnification makes it is possible to count the warp (parallel threads) and weft (the threads that go above and below the warp), and in forensic work this can help in identifying a specific manufacturer's cloth. Single threads can be removed from the fabric, mounted on a microscope slide and examined.

Some details of a fabric sample can be seen with a hand lens. Removing a thread from the sample enables it to be examined using a microscope.

It is helpful to explain to the students that they can remove threads from a piece of fabric, but the fibres are often very intertwined so it is difficult to obtain just one fibre. However, sometimes the threads themselves are difficult to tease from the fabric. This could be because the threads are so fine that they are difficult to get a purchase on, or a fabric treatment could have been added and this may act as an adhesive between the threads.

HOW ARE FIBRES MADE?

As discussed earlier, fibres can be obtained from natural sources or they can be manufactured synthetically: the fibres can be twisted together to form a thread, and the threads woven together to form a fabric. After students have gained an understanding of these terms and have examined samples of threads and fabrics, there are a number of demonstrations they could be shown that illustrate how fibres can be made.

Classroom activities

See Activity X1
Where does silk come from? (page 43)

Silk is a natural fibre made from the cocoon of a silk worm. The cocoon can be unravelled to obtain a continuous fibre of silk. In silk production, the fibre can be used directly, or more than one fibre can be wound together to form a silk thread.

A silkworm cocoon can be cut in half to reveal what is inside (left), and after soaking in warm water, a fibre can be pulled from a cocoon (right).

The most commonly used synthetic fibre is nylon, and is made from the reaction between a dicarboxylic acid and a diamine to make a polyamide polymer. A classic demonstration experiment in the school laboratory is the ‘nylon rope trick’ in which a nylon fibre is made by reacting together 1,6-diaminohexane dissolved in water and decanoyl chloride dissolved in cyclohexane (instructions are provided on the *RSC* website - see *References and further reading* on page 53). Since the two monomers dissolve in different immiscible solvents, the nylon is made at the interface between them. By drawing the denser layer through the top layer, a thread is formed.

Nylon was used as a replacement for silk to make parachutes during World War II.

Nylon was invented in the 1930s and the first nylon product was a toothbrush; however during World War II it was used to make parachute canopies, because silk was a commodity in short supply and nylon had similar properties to silk.

It is also possible to demonstrate making rayon in the laboratory (instructions are provided on the *Practical Chemistry* website - see *References and further reading* on page 53). Rayon is a fibre made from regenerated cellulose, and the material has many similar properties and uses as silk. The cellulose can come from wood pulp or cotton and then chemically treated to make rayon. The best material to use in the school laboratory is cotton wool. The fibres in this can be broken down by dissolving the cotton wool in a mixture of ammonia solution and copper carbonate, and the rayon produced by extruding this into a bath of dilute sulfuric acid.

Rayon can be made by regeneration of natural cellulose fibres obtained from cotton wool.

Note that the rayon made by this method is quite unrefined and therefore brittle compared to commercially available thread. The classification of rayon is difficult, as it is made of natural cellulose fibres but they have been re-arranged by a chemical reaction. Therefore, as a How Science Works extension activity you could split the class into two groups and debate the motion that rayon is a natural fibre. You could also ask students to compare the properties of rayon thread with silk thread.

PROPERTIES OF FIBRES

Sometimes new applications can be found for existing materials. Increasingly, however, specialist synthetic fibres, threads and fabrics are being manufactured to have targetted properties and to be used for a specific job.

Synthetic fibres tend to be stronger that natural fibres. This is because synthetic fibres are made of uniform polymer chains that readily line up forming a very long crystal. This results in strong intermolecular forces and therefore a strong fibre. However, some brittleness will result from such a uniform structure. Natural fibres have a natural variation in structure. The polymer chains (cellulose from plants or protein from animals) do not line up as regularly and this makes natural fibres weaker than synthetic ones. Fibres tend to be stronger when a load is applied along the length of the fibre rather than perpendicular to the fibre. In order to maximise the strength of a fibre, more than one material may be used to make a composite.

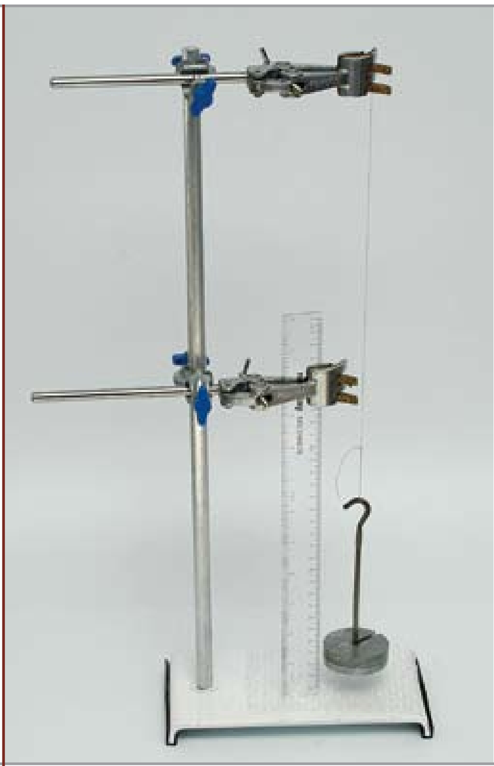
In some parts of all fibres, the polymer chains may be amorphic ('jumbled up'). When a load is applied, the chains unravel slightly, and when it is removed they will spring back to their original shape. This is *elastic* behaviour. However, if too much load is applied, the intermolecular forces between the polymer chains get irreparably disturbed and the fibre will change shape. This is *plastic* deformation. Synthetic fibres can be engineered with a lot of amorphic regions, creating a very elastic fibre.

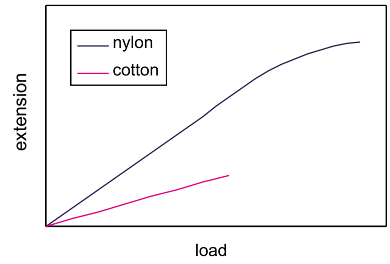
Classroom activities

Students can do simple tests on the strength and elasticity of threads. By securing a known length of thread to a bosshead and suspending masses onto it, the extension can be measured. Different materials will behave differently. For example, for nylon, the thread will initially behave elastically following Hooke's Law. However, when the elastic limit has been reached the thread will plastically deform. A comparable cotton thread will be less elastic and will break more easily.

See Activity A2
Do all threads stretch the same amount? (page 30)

Threads made of different materials exhibit different properties when a load is applied to them.



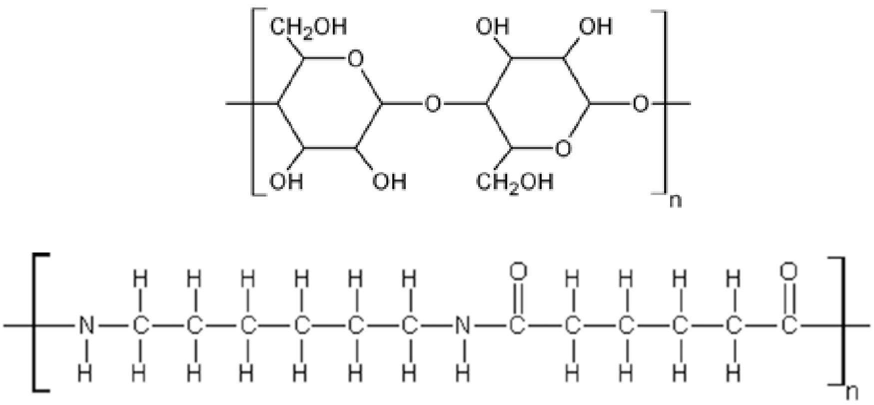


PROPERTIES OF FABRICS

An important property of a fabric is its water resistance. Even though many fibres themselves are waterproof, when they have been made into a fabric the holes or pores in the fabric may absorb water. This means that they have different microscopic and bulk properties.

Some fibres like cotton absorb water very easily and are describe as hydrophilic. This is because cotton is made from cellulose which has many hydroxyl groups – these are attracted strongly by hydrogen bonding to water molecules. The oxygen atoms (∂^-) in the water molecules are attracted to the hydrogen atoms (∂^+) on the cellulose polymer chain and vice versa. However, nylon has fewer places for hydrogen bonds to form between the polyamide polymer chain and water molecule. This means that nylon will absorb less water than cotton. Cotton can absorb up to 25% of its weight of water, whereas nylon can only absorb 10%.

Cotton absorbs water better than nylon because the cellulose molecules in cotton (left) have many hydroxyl groups which can form hydrogen bonds to water. Nylon molecules (right) have fewer sites where water molecules can hydrogen bond.



Sometimes, water absorbency is useful – this can be maximised by increasing the surface area of the threads for example by making loops as in the manufacture of towelling. Where waterproofing is required, fabrics can be treated by adding a filler chemical to remove the pores created when threads are woven into a fabric. In Gore-Tex, waterproofing is achieved by using a number of different layers, one of which is a waterproof membrane.

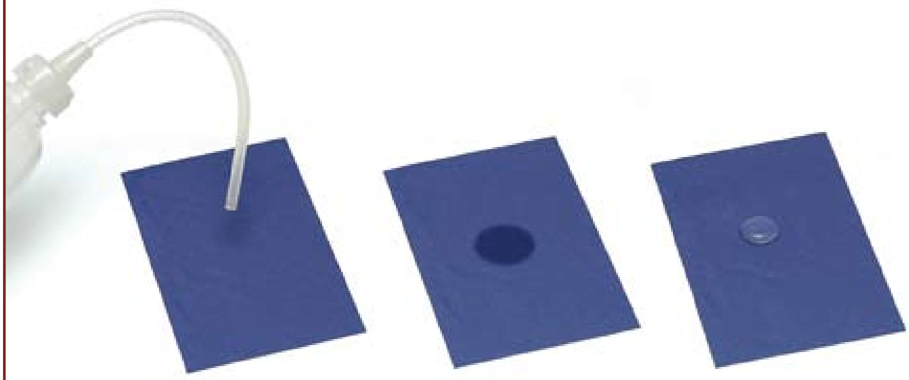
Another important property of fabrics concerns their thermal insulation. Most natural fabrics are excellent insulators, because they contain pockets of air that reduce the transfer thermal energy. House insulation is often made from glass fibre but it can be made from the fleece of shorn sheep. This is becoming a more desirable form of insulation as the price of wool is decreasing and the insulation is sustainable and environmentally friendly.

Classroom activities

See Activity A3
Waterproof nature of fabrics (page 32)

To introduce the idea of waterproofing a fabric, take a swatch of cotton and squirt some water from a wash bottle. Encourage the students to notice that the water is absorbed by the fabric. Then take an identical swatch of fabric, rub the surface with wax and then spray water. They should notice that the material has become waterproof.

Fabrics can be made waterproof by coating with a waterproof material such as wax.



The water absorbency of a fabric can be tested by comparing the mass of a sample before and after immersing it in water.

Students can use a hand lens to examine a cloth to see if it contains pores and consider how waterproof they think it will be. By measuring the mass of a dry sample, immersing it in water and measuring the new mass, students can find out how much water is absorbed by the fabric. Fabrics that are waterproof should have a smaller difference in mass between the two readings.

Students could also do a research task on waterproofing by using secondary sources and write an article for other students in their class – their work could be peer reviewed.

See Activity A4
How are fabrics made waterproof? (page 33)

Using a mini-hotplate and an infrared thermometer to compare the insulating properties of different fabrics.

A simple way of testing the insulating properties of fabrics is by using an SEP Mini-hotplate. When placed on the plate, fabrics that are good thermal conductors will quickly become the same temperature as the hot plate.

The top surface of a fabric that is a good thermal insulator will remain cooler than the hot plate for longer. To measure how quickly the top surface warms up, students can use an infrared thermometer; the hotplate can be set to 50 °C and the time taken for the fabric surface to reach 40 °C measured.

See Activity A5
How well do different fabrics insulate? (page 34)

Some students may have difficulties with the idea that the fabric with the *lowest* temperature is the *best* insulator – they need to understand that this is because a good insulator acts as a *barrier* preventing thermal energy moving from the hot plate to the surface of the fabric.

Students could evaluate other methods of investigating insulation properties of fabrics.

Students could consider other methods of investigating the insulating properties fabrics and evaluate whether the mini-hotplate technique is the best option. For example, they could wrap a piece of fabric around a conical flask full of warm water and monitor the temperature of the cloth, or they could measure the change in temperature of the water inside the flask.

To extend this investigation, students could also look at the effect of adding more layers of the same material and thus trapping more air. They should predict that the greater the number of layers, the greater the insulation property of the material.

TREATING FABRICS

The aesthetic properties of threads and fabrics are very important. Dyes can be used to create a myriad of colours and effects. The earliest record of dyeing was in China 2600 BC. It has only been since the 19^{th} century that synthetic dyes have been available. Before this time, all dyes were made from plants or minerals. Many vegetables like onions and beetroot can be used to make a simple vegetable dye. Other natural dyes can be made from tea, coffee and turmeric. These dyes can be used to change the colour of a wide variety of materials including hair and fabrics.

Animal fibres such as silk consist of proteins, while many plant fibres such as cotton consist of cellulose. The chemical differences between these molecules mean that some dyes are more strongly attracted to proteins and other dyes more strongly attracted to cellulose. This means that dyes that are effective with animal fibres tend not to be so with plant fibres and vice versa. Once a fabric has been dyed, the colour can fade due to washing, light or other environmental conditions.

Over time the colour of a dyed fabric will tend to fade.

If a dye does not wash out it is known as colourfast. A special chemical called a mordant can be added during the dyeing process which can ensure that a dye becomes colourfast. A mordant forms an insoluble compound with the dye, and this prevents it from going into aqueous solution when the dyed fabric gets wet. Common mordants include alum, tannic acid and sodium chloride.

A dye that is colourfast chemically bonds to the fibres. Soap molecules, however, physically interact with the fibres. Their hydrophilic head dissolves in water, and their hydrophobic tail dissolves in grease to allow the grease to emulsify in the washing water.

Often fabrics are required to be cleaned using a soap or a detergent. The head of a soap molecule is negatively charged and is hydrophilic (attracted to water), while the tail is an organic molecule and is hydrophobic (repelled by water). During washing, the tail therefore dissolves in the grease on clothes and the head dissolves in the water. In hard water areas, soap reacts with the dissolved calcium and magnesium ions to form insoluble salts known as 'scum'. After the hardness had been removed the soap will then foam. Soapless detergents act in a similar way to soap, but do not form a precipitate and will foam no matter how hard the water is.

See Activity A6
What is the history of fabric dyeing?
(page 36)

See Activity A7
Making natural dyes
(page 37)

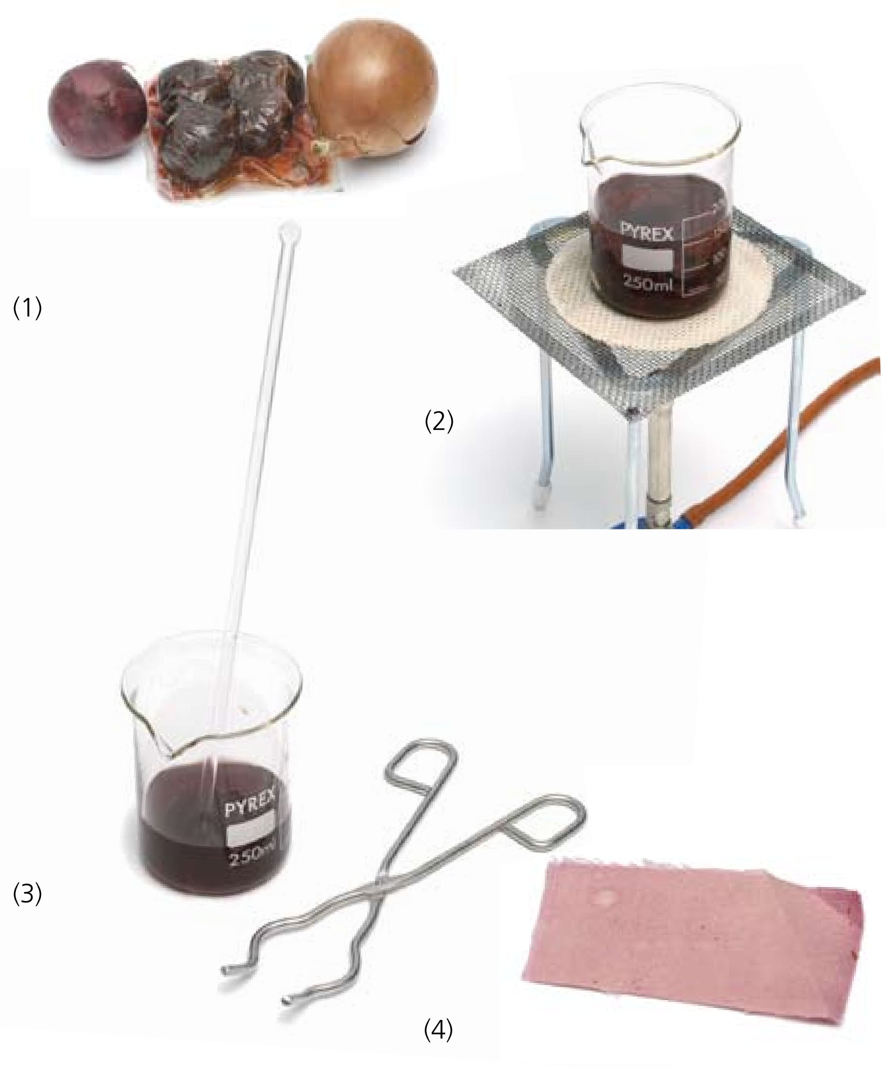
Classroom activities

Using secondary sources students can create a timeline to show how dyeing has developed in history. Encourage students to use a variety of resources to generate their timeline, and to display their timeline in different ways, for example, a flow chart, prose, poster, TV programme, pod cast. Exemplar materials could be uploaded onto the school website for other students to compare.

Students can experiment with making their own dyes from natural sources. They will have had the experience of dropping fruit and vegetables on their clothes and a coloured stain forming. The stain may not even wash out. This is an example of a natural dye.

Beetroot, red onion and red cabbage all contain anthocyanin and white onion contains quercitin; these are the active natural chemicals which dye the fabric. The active chemical can be removed by boiling the vegetable, and since the chemical is water soluble, the cooking liquor becomes the dye. The fabric can then be immersed and coloured.

Natural dyes can be obtained from a variety of vegetables (1). The dye can be removed by boiling the vegetable in water (2), then filtering to remove the solid matter and stirring the fabric in the liquor (3). The dyed fabric can then be left to dry (4).

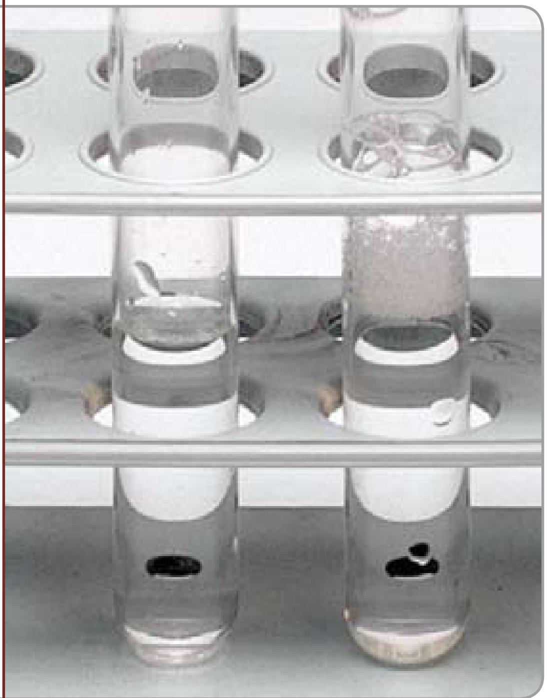


Some dyes are not colourfast and the dye will dissolve when put into water.

After drying the fabric can be tested for colourfastness by dipping it into water. The colour of the dye will be darker when the material is wet. Natural dyes will colour natural fabrics like muslin, silk, cotton, linen and wool better than synthetic materials.

To extend students further, they could see how to increase the colourfast nature of the dye by using a mordant, or find out how to make dyes resistant to fading due to light.

Hardness of water affects the foaming ability of soap (left) but not detergent (right).



See Activity X2
Soap and detergent
(page 44)

Soap and detergents are both used to remove dirt and grease from fabrics. As an introduction, students could be given four test tubes of water – two of hard water and two of soft water. They should add samples of soap and soapless detergents to each type of water and shake the test tubes. They should then be able to see that soapless detergents always foam, whereas soap only foams when all the hardness (dissolved magnesium and calcium ions) have been removed.

Students could also use secondary sources to make a poster that describes the differences and similarities between detergents and soaps.

SMART FABRICS AND PIGMENTS

Smart materials are an emerging class of materials whose properties change as their environment alters. The changes in properties are brought about by a particular *stimulus*, for example, changes in pH, temperature or light. Smart fabrics can be used to make garments whose properties change in interesting ways when subjected to a stimulus. An example is the use of smart pigments in fabrics which can change colour according to the temperature. Applications of these pigments include thermometers, specialist medical equipment indicates the temperature to warn people if food is too hot, fun cups and clothing as a fashion statement.

Temperature change is the stimulus for this smart material.

Another pigment that can be used in fabrics is phosphorescence pigment – this emits light in the dark. Phosphorescence should not be confused with fluorescence. Phosphorescence occurs when a material continues to emit light after a light source is removed. This is due to electrons being excited into a higher energy level. As the electrons drop back into the lower energy level they release photons. If the wavelength is within the visible region, this will be seen as a coloured light. Fluorescence is similar but in this case the electrons drop back almost immediately, and as soon as the light source is removed, the fluorescence will stop.

Classroom activities

See Activity A8
Thermochromic pigments
(page 39)

Students can prepare a sample of thermochromic pigment that can be painted onto fabric and heat it up until it changes colour. The temperature at which the colour change occurs is its *transition temperature*. To prepare the paint, a small quantity of the pigment is mixed using a paintbrush with normal acrylic paint – this can be painted onto a swatch of fabric and then left overnight to dry.

The thermochromic pigment is mixed within an acrylic paint for application onto a fabric.

The transition temperature of the pigment is lower than body temperature, and so the colour change can be seen simply by warming the swatch of fabric between the hands. When the transition occurs, the pigment becomes transparent. There are a number of different colours of thermochromic pigment available but they all become colourless upon warming.

As the fabric is warmed, the pigment becomes colourless.

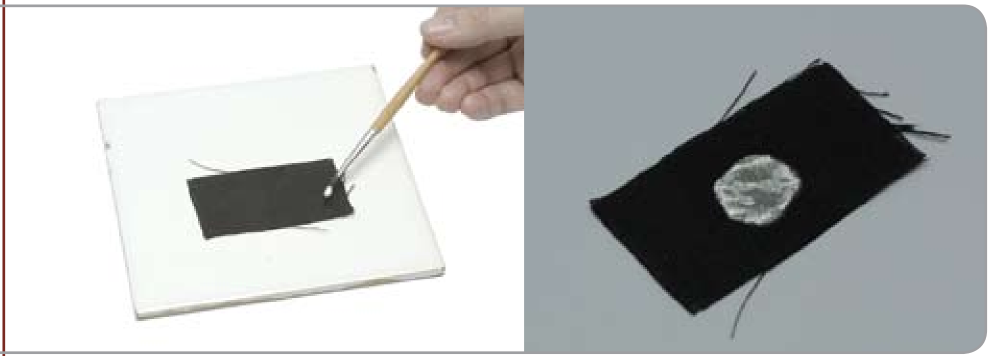
A thermochromic pigment will change colour at an exact temperature – the transition temperature.

To find the exact transition temperature, students can slowly heat their swatch of fabric with the thermochromic pigment, and measure the temperature with an infrared thermometer. This can be conveniently done by putting the fabric on a white tile over a beaker of hot water and observing the colour of the pigment. The temperature at which the colour change occurs is the transition temperature.

See Activity A9
Phosphorescent pigments
(page 41)

Students can also prepare a swatch of fabric with phosphorescent pigment in a similar way. The phosphorescent pigment is mixed with an acrylic paint and painted onto the fabric. After exposing the pigment to light, it will glow when the light source is removed.

Fabric can be painted with a phosphorescent pigment to make it glow in the dark.



The pigment is activated by UV light, but this includes natural daylight and the light from an electric bulb since these contain frequencies from the UV part of the electromagnetic spectrum.

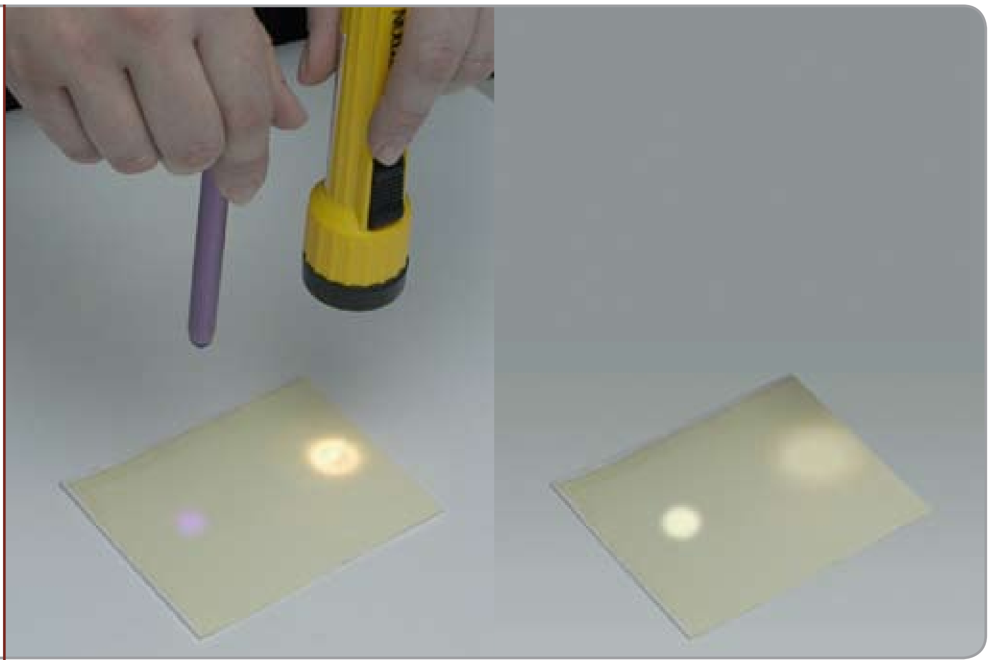
Investigating the effect of different exposure times on the glow-in-the-dark film.

Students can investigate the effects of different light sources on the pigments, but rather than using the fabric swatches, it is more convenient to use phosphoresent film ('glow-in-the-dark' film). Using the film will produce more reliable results since coating large areas of fabric evenly with phosphorescent pigment is not easy.

Using a torch as a light source, students should find that as the light source gets brighter, the phosphorescence increases. The phosphorescence also increases as the exposure time gets longer.

Using a torch and a 'UV energiser' allows comparisons to be made between the effects of different frequencies of light. Students should find that even though the torch may produce a brighter patch of light on the film than the UV pen, when the light source is removed, the film glows more where it was exposed to UV light. This is because the phosphorescent pigment is excited by the higher frequencies of radiation.

Comparing the effects of visible and UV light.



NEW DEVELOPMENTS

The definition of a smart fabric varies between scientists and technologists. Scientists tend to define smart materials as those whose properties change in response to a stimulus by a change in the chemical or physical structure. However, technologists may define smart materials in terms of whole solutions integrating technologies together, such as a jacket with electrical wiring for using headphones connected by Bluetooth to a mobile phone.

Innovative examples of smart fabrics include:

ElekTex A British company, Eleksen, has designed a three-layer smart fabric that allows electrical current to run through it. It is hoped that in the future it can be used to make touch-sensitive control pads on clothing that could control things like mobile phones and MP4 players.

Luminex An Italian based company of the same name has designed a smart fabric that shimmers. They have incorporated optical fibres into the fabric and used this to make high-fashion clothing like shawls. Practical applications could be generated for the fabric such as high-visibility garments for the emergency services.

Heatech Japanese technology is being harnessed to create a new fabric which promises to absorb body moisture, and as the droplets move through the soft fabric heat is generated keeping the wearer warm. This has applications for specialist mountaineering clothing.

A lot of fabric developments are currently happening in the sports clothing industry to improve the performance of athletes. Many of these advances for the top athletes filter down into the major high street markets within a few years of being featured on the international sporting scene.

STUDENT ACTIVITIES

FIBRES AND FABRICS

Teachers' notes

The student materials consist of a series of practical activities that involve the analysis of fibres and fabrics, and some research activities using secondary sources. The materials are intended for use at KS4, though some of the materials could be adapted for use at KS3. The key ideas are concerned with:

- observation and identification of different fibres, threads and fabrics
- differences in the strengths and elasticity of natural and synthetic threads
- water-resistant and insulating properties of different fabrics
- treatment of fabrics using dyes and pigments
- selection of suitable materials for different applications
- smart materials and new developments in textile technology.

To help students to understand the terminology used in the activities, there is a resource sheet *Glossary of technical terms* (see page 50). It may be helpful to clarify with students some of these terms, particularly *fibre, thread* and *fabric*, which are used extensively in the activities.

Two packs of practical resources have been produced to support the work in this publication and are available from Middlesex University Teaching Resources. The SEP Fabric sample pack contains samples of cotton, Gore-Tex™ (two-layer), Gore-Tex™ (three-layer), linen, Kevlar™, Lycra®, nylon (plain), nylon (ripstop), silk, Teflon-coated polycotton and Thinsulate™. The SEP Threads testing pack contains cotton, nylon, polyester and silk threads.

Visit the SEP website www.sep.org.uk for supporting resources including image files and editable versions of the student sheets. See page 55 for information on obtaining the practical resources.

An overview of the activities

The activities are:

- **Activity A1** Collection and microscopic analysis of threads
- **Activity A2** Do all threads stretch the same amount?
- **Activity A3** Waterproof nature of fabrics
- **Activity A4** How are fabrics made waterproof?
- **Activity A5** How well do different fabrics insulate?
- **Activity A6** What is the history of fabric dyeing?
- **Activity A7** Making natural dyes
- **Activity A8** Thermochromic pigments
- **Activity A9** Phosphorescent pigments

There are two extension activities:

- **Extension X1** Where does silk come from?
- **Extension X2** Soap and detergent

In addition, there are resource sheets that provide additional information:

- **Resource R1** Fact sheets on fibres and fabrics
- **Resource R2** Glossary of technical terms

Notes on the activities

Activity A1: Collection and microscopic analysis of threads

Students use microscopic comparisons to identify commercially available threads, and samples of threads taken from different fabrics (see also page 5 of this booklet 'Examination and identification').

LEARNING OBJECTIVES

Students will:

- mount thread samples and observe using a microscope
- collect thread samples from fabrics and identify them
- relate this microscopy technique to a real-life application
- explain how forensic scientists ensure that their samples are not contaminated.

NOTES

Be aware that some students may have allergies to materials and dyes. Check, by asking, whether any students in your class are affected and take appropriate action.

You may wish to use a digital microscope to show the students these threads and fabrics as a demonstration. The results could be made more reliable by analysing more samples from the same fabric and checking that the observations were the same. The accuracy of the results could be checked by comparing the results to published results.

Note that dry threads and wet threads will look different. As an extension, you could ask students to make a wet mount of a thread by adding a drop of water, and then to compare this to a dry mount of the same type of thread.

RESOURCES NEEDED

Each group will need:

- Small plastic bags labelled A, B, C and D containing samples of threads (from SEP Threads testing pack: containing cotton, nylon, polyester and silk threads)
- SEP Fabric sample pack: containing samples of cotton, Gore-Tex (two-layer), Gore-Tex (three-layer), linen, Kevlar, Lycra, nylon (plain), nylon (ripstop), silk, Teflon-coated polycotton and Thinsulate
- 8 microscope slides
- Sticky labels
- Sticky tape
- Scissors
- Microscope
- Hand lens
- Tweezers
- *Resource R1: Fact sheets on fibres and fabrics.*

Activity A2: Do all threads stretch the same amount?

Students find out about the strength and elasticity of different fibres by hanging masses from them and plotting a graph of extension against load (see also page 9 of this booklet 'Properties of fibres').

LEARNING OBJECTIVES

Students will:

- compare the differences in strength and elasticity between natural and synthetic threads
- collect and manipulate quantitative data
- draw and interpret a line graph
- evaluate the reliability of their results.

NOTES

Ensure that students place the apparatus in such a way that the masses are unlikely to fall on to toes.

Nylon stretches more than cotton so it is better to start with nylon to see the results more clearly. Cotton is not as elastic as nylon, and it will break more easily with a smaller load. Nylon will stretch elastically with small loads; with larger loads it may begin to stretch plastically (i.e. deforming before it breaks).

The data could be plotted using a computer spreadsheet, though the line of best fit will need to be drawn by hand.

RESOURCES NEEDED

Each group will need:

- SEP Threads testing pack: containing cotton, nylon, polyester and silk threads
- Clamp stand, 2 bossheads and 2 clamps
- Ruler
- 100 g slotted masses and holder
- Bubble wrap or similar for padding.

Activity A3: Waterproof nature of fabrics

Students make predictions about which fabrics will be waterproof and investigate if their predictions are correct (see also page 10 of this booklet 'Properties of fabrics').

LEARNING OBJECTIVES

Students will:

- make visual observations to predict which fabrics will be waterproof
- investigate which fabrics are waterproof
- evaluate their experiment and suggest ways to improve it.

NOTES

Some fabrics do not wet easily if they have air trapped in them so students need to make sure they are well stirred – if necessary they can leave them immersed for longer that the time specified.

As an additional test, after draining the fabric sample and weighing it, the fabric could be blotted (e.g. with filter paper) and weighed again to see how much water has been retained. Blotting the fabric absorbs water that through capillary action remains on the surface of the fibres.

This experiment is not a fair test of clothing fabrics as they are mainly designed to be waterproof from one side only. It is possible to make this test more realistic by holding the fabric in a clamp on a clamp stand, and using water spray to add a set amount of water to one side of the fabric. Again the mass before and after the addition of the water should be measured.

RESOURCES NEEDED

Each group will need:

- SEP Fabric sample pack: containing samples of cotton, Gore-Tex (two-layer), Gore-Tex (three-layer), linen, Kevlar, Lycra, nylon (plain), nylon (ripstop), silk, Teflon-coated polycotton and Thinsulate
- Hand lens
- Tweezers
- Stirring rod
- Beaker, 250 cm^3
- Access to electronic balance.

Activity A4: How are fabrics made waterproof?

Students research websites and other sources to find out how fabrics can be made waterproof (see also page 10 of this booklet 'Properties of fabrics').

LEARNING OBJECTIVES

Students will:

- use a variety of secondary sources to research natural and synthetic fabrics
- describe how fabrics can be made naturally and designed to be waterproof
- write their findings in a concise manner suitable for a specified audience
- give constructive feedback to their peers.

NOTES

As a quick starter you could take a swatch of cotton and, using a water spray, show how the fabric absorbs the water. Take another swatch of cotton, rub a wax crayon on the surface and repeat the demonstration. This is one method for making the cotton fabric waterproof.

As an extension to this activity, students could produce their article using a desktop publishing package.

Once the peer review has been completed, students could be asked to make modifications to their article as homework and to hand in the revised work for marking.

RESOURCES NEEDED

Access to research tools e.g. school library, Internet, and specialist publications.

You may wish to give students Resource *R1: Fact sheets on fibres and fabrics* to help them.

Activity A5: How well do different fabrics insulate?

Students compare two different methods to investigate the insulating properties of different fabrics: by using a hotplate and an infrared thermometer, and by using hot water in a conical flask (see also page 10 of this booklet 'Properties of fabrics').

LEARNING OBJECTIVES

Students will:

- recognise that different fabrics have different insulating properties
- collect and record quantitative results
- draw conclusions consistent with the results
- evaluate two methods and suggest improvements.

NOTES

CAUTION: Students should be aware that the mini-hotplate can become very hot, and should take care not to handle it when hot. If a hotplate is not available, hot water in a beaker could be used.

Lower-achieving students may find the bar chart and line graph difficult to complete. Give these students squared paper rather than graph paper with the axes and scale already drawn. For Task B, you may wish to discuss the idea that the independent variable is not continuous therefore the data cannot be shown on a line graph.

Instead of using a thermometer, students could use a datalogger with temperature probe. This allows discussion about whether the graph actually shows a true line of best fit. A differential thermopile could also be used to monitor the insulation properties of the fabrics.

You may wish to only complete one method, or have half the class complete one method and the remaining students use the second method. Then the whole class can work together on evaluating the two methods.

RESOURCES NEEDED

Each group will need:

TASK A

- Three different samples of fabric (e.g. cotton, nylon, linen, Lycra or Thinsulate), approximately 7 cm square
- SEP Mini-hotplate
- Power supply (12 V, 2 A d.c.)
- 2 plug-plug leads (1 red, 1 black)
- Infrared thermometer
- Stopclock.

TASK B

- Three different samples of fabric (e.g. cotton, nylon, linen, Lycra or Thinsulate), each large enough to wrap a conical flask
- 3 conical flasks, 250 cm^3
- 3 thermometers, -10 °C – 110 °C
- Sticky tape
- Scissors
- Stopclock
- Access to a kettle.

Activity A6: What is the history of fabric dyeing?

Students research websites and other sources to generate a timeline showing how the dyeing of fabric has changed over hundreds of years (see also page 13 of this booklet 'Treating fabrics').

LEARNING OBJECTIVES

Students will:

- use a variety of secondary sources to research the history of dyeing fabrics
- describe the difference between natural and synthetic dyes
- write their findings in a concise manner suitable for a specified audience.

NOTES

As an extension to this activity, students could make their timeline on a desktop publishing package.

You could make one large timeline for a display in the classroom. Give each student or small group a time frame to research and generate a poster about fabric dyeing in this period. Once the timeline has been mounted on the wall, students could be encouraged to draw conclusions. Students should conclude that natural dyes were the first to be developed; only in the more recent past have there been large numbers of synthetic dyes available.

Useful websites are listed in the *References and further reading* section on page 53.

RESOURCES NEEDED

Access to research tools e.g. school library, Internet, and specialist publications.

You may wish to give students Resource *R1: Fact sheets on fibres and fabrics* to help them.

Activity A7: Making natural dyes

Students make their own dye using beetroot or other natural sources, test these on different fabrics and then investigate the colourfast nature of their dye (see also page 13 of this booklet 'Treating fabrics').

LEARNING OBJECTIVES

Students will:

- make their own natural dye for fabrics
- plan and test the colourfastness of their dye
- draw conclusions consistent with data.

NOTES

Students should write a full plan on how they could test the colourfastness of their dye. Weaker students may require a writing frame, or even the steps of the method given to them as a card sort or cut-and-stick activity.

Encourage students to discuss their plan in small groups and to determine the independent, dependent and control variables. They should also consider how reliable, accurate and sensitive their results will be. You must check all plans before allowing the students to carry out any practical activity.

You may wish to allow the students to investigate other natural dyes e.g. using onion skins. You should be aware of food allergies and intolerances in this activity. They could also try using vinegar as a mordant, by submerging the fabric in four parts cold water to one part vinegar and simmering for one hour. After rinsing the fabric in water and squeezing out the excess, it can be dyed with the solution obtained from the boiled vegetables.

RESOURCES NEEDED

Each group will need:

- Samples of cotton, nylon and silk fabric
- Beaker, glass, 250 cm^3
- Chopped beetroot
- Water
- Hotplate (NB not the mini-hotplate) or Bunsen Burner, tripod, gauze and safety equipment
- Filter funnel
- Filter paper
- Conical flask, 250 cm^3
- Glass rod
- Tongs
- Stopclock
- Student's own choice of equipment to test colourfastness e.g. water at different temperatures, detergent, soap, stopclock, access to a washing machine.

Activity A8: Thermochromic pigments

Students make a paint from thermochromic pigment to put on a fabric and then find the transition temperature of the pigment (see also page 16 of this booklet 'Smart fabrics and pigments').

LEARNING OBJECTIVES

Students will:

- make a thermochromic fabric paint from a specialist pigment and synthetic base
- determine the transition temperature of the thermochromic pigment
- evaluate the experiment and state how it could be improved.

NOTES

CAUTION: Students should wear disposable gloves and eye protection when using the thermochromic pigment.

The transition temperature is 27 °C. This is when the colour of the pigment changes to colourless and so you only see the colour of the acrylic base (white). Note, however, that since the acrylic base is water soluble, this paint could not be used to make real clothing.

Following the practical, encourage students to consider applications for thermochromic pigments e.g. thermometers.

Useful websites are listed in the *References and further reading* section on page 53.

RESOURCES NEEDED

Each group will need:

- Samples of fabric (e.g. cotton, nylon, linen, Lycra, silk)
- Thermochromic pigment and acrylic base from the 'Smart colours starter pack'
- White tile
- Paint brush
- Infrared thermometer
- Beaker, glass, 250 cm^3
- Stopclock
- Access to a freezer and to a kettle.

Activity A9: Phosphorescent pigments

Students make a paint from phosphorescent pigment to put on a fabric and then explore the effect of light on phosphorescent pigments (see also page 16 of this booklet 'Smart fabrics and pigments').

LEARNING OBJECTIVES
Students will:
- make a phosphorescent fabric paint from a specialist pigment and synthetic base
- collect quantitative results
- draw conclusions consistent with the data that has been collected.

NOTES
CAUTION: Students should wear disposable gloves and eye protection when handling this pigment and the resulting paint. Students should wear UV filtering eye protection when using the UV pen.

The paint should spread easily onto the fabric, but if the mixture seems too thick, students can use a dropping pipette to add drops of water and mix thoroughly to get the consistency they want.

RESOURCES NEEDED
Each group will need:

TASKS A and B
- Samples of fabric (e.g. cotton, nylon, linen, Lycra, silk)
- Phosphorescent pigment and acrylic base from the 'smart colours starter pack'
- White tile, paint brush.

TASKS C and D
- Torch
- UV pen ('energiser') and power supply
- Stopwatch
- Ruler
- Phosphorescent film
- UV filtering eye protection.

Extension X1: Where does silk come from?

This is a teacher demonstration of how silk fibre can be obtained from a silk worm cocoon (see also page 7 of this booklet 'How are fibres made?').

LEARNING OBJECTIVES
Students will:
- be able to make and record quantitative results
- be able to use secondary and primary data to compare materials.

NOTES
You may wish to split the class into small groups and repeat the demonstration a number of times. The rest of the class could be completing the final section of the activity. Alternatively, a digital camera connected to a projector could be used to magnify the demonstration.

Use dissecting scissors to cut into one of the cocoons. Then dip another whole cocoon in hot soapy water. Using your nails, or dissecting tweezers, find a loose fibre and then pull to unravel the cocoon.

RESOURCES NEEDED
- Silk worm cocoon
- Dissecting scissors
- Tweezers
- Beaker, 250 cm^3.

Extension X2: Soap and detergent

Students research websites and other sources to create a poster comparing the differences between soap and detergent (see also page 13 of this booklet 'Treating fabrics').

LEARNING OBJECTIVES
Students will:
- use secondary sources to research a topic
- produce a suitable poster for a specific audience
- undertake and comment on a peer review of work.

NOTES
Lower-achieving students could be given unlabelled diagrams and short sentences of key facts to help them sort out whether the information refers to soap or detergents.

As an extension to this activity, students could produce their poster using a desktop publishing package.

RESOURCES NEEDED
Access to research tools e.g. school library, Internet, and specialist publications.

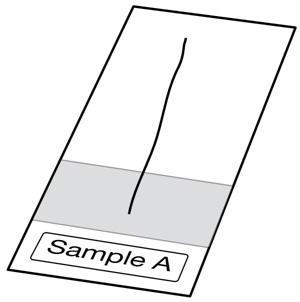
You may wish to give students *Resource R1: Fact sheets on fibres and fabrics* to help them.

FIBRES AND FABRICS:
COLLECTION AND MICROSCOPE ANALYSIS OF THREADS

A criminal will often leave a trail of evidence at a crime scene. Specially trained police officers can find and remove fibres and threads from the scene. This evidence can be used to work out what a suspect was wearing. In this activity, you are going to use a microscope to identify different threads.

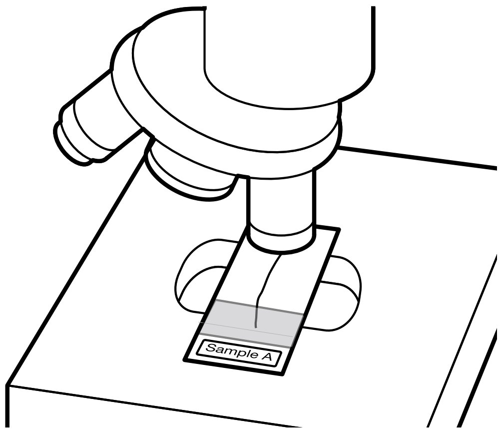
Task A
Observing differences between threads

1. You will need a selection of 'unknown' threads to identify.
2. Cut a small length (2-3 cm) of the first thread. Put it in the centre of a microscope slide and fix in position with a piece of sticky tape. On a sticky label write 'Sample A' and stick this to the microscope slide.
3. Make a separate microscope slide for each thread.
4. Draw a suitable results table for your data.



Sample	Observations	Identity
A		

5. Set up a microscope to the smallest magnification. Make a note of the magnification (eye piece x objective lens).
6. Using the microscope, study each sample. In the second column of the table, make a note of the colour, the texture (twisted, smooth or scaly) and any other features that strike you.
7. Use the images on the following page to identify each sample. Write this in the third column of the table.



In a real forensic lab, the scientists would use a comparison microscope. This would have the unknown sample of one side and reference sample on the other, to make visual comparison easier.

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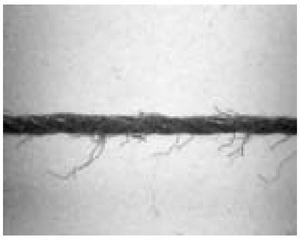
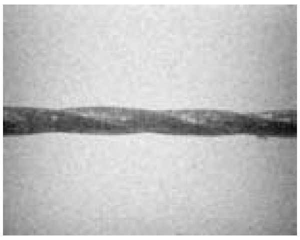
FIBRES AND FABRICS:

COLLECTION AND MICROSCOPE ANALYSIS OF THREADS

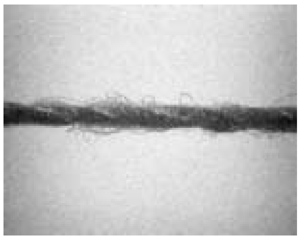
The images of the threads shown below were taken using a digital microscope. They are shown here at 10x magnification.



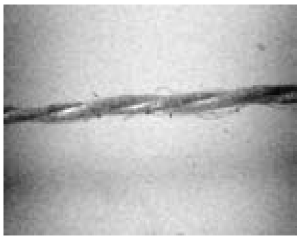
cotton



nylon

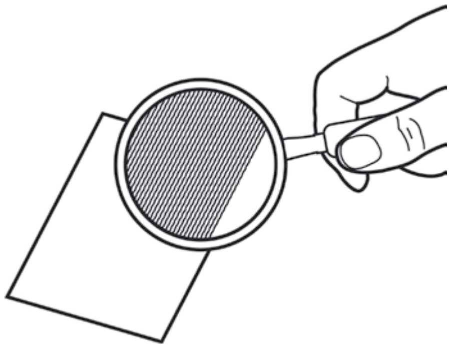


polyester



silk

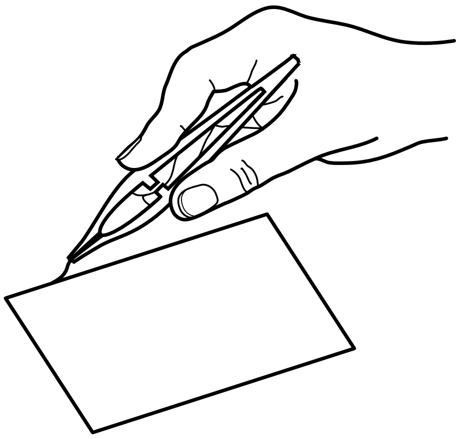
Task B Threads from fabrics



8. You will need a selection of different fabrics in plastic bags, and Resource *R1: Fact sheets on fibres and fabrics.*

9. Use a hand lens to look carefully at your samples of fabric. Do they all have threads?

10. Use a pair of tweezers and pull a thread from one of the fabrics.



11. Look at the fibre under the microscope.

12. Using the fact sheets and your observations, can you identify the fabric?

13. Repeat this for other fabrics.

14. For forensic analysis, why is it important that each fabric is in a separate sealable plastic bag?

15. Why is it important that you wear a lab coat for forensic investigations?

16. How could you check the reliability and accuracy of your results?

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FIBRES AND FABRICS: DO ALL THREADS STRETCH THE SAME AMOUNT?

When a force is applied to a thread it will stretch. Threads that stretch *elastically* return to their original shape when the force is removed. The thread obeys Hooke's law, since the extension is proportional to the force or load. But, if the thread does not return to its original shape, it will have gone past its elastic limit and has been *plastically* deformed. The thread no longer obeys Hooke's law.

Task A
Testing the threads

1. Use a ruler to measure 25 cm lengths of each thread you want to investigate.

2. Tie a loop at each end of the threads.

3. Set up a stand, bossheads and clamps, with a ruler as shown in the diagram.

4. Draw a suitable table for your results.

	Nylon		Cotton	
Mass (g)	Reading (cm)	Extension (cm)	Reading (cm)	Extension (cm)
100				
200				

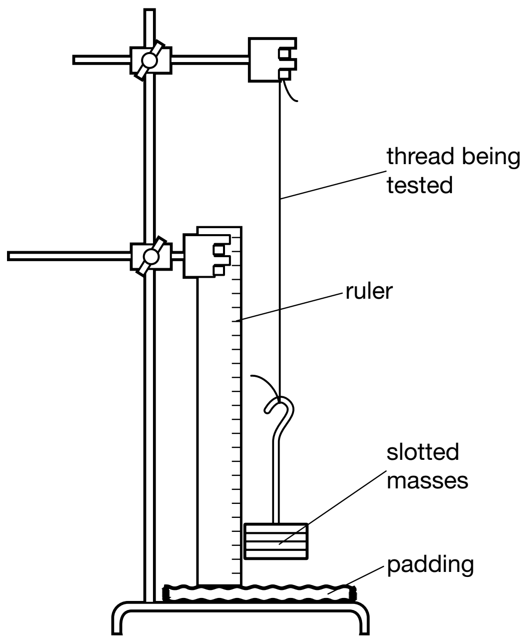
5. Attach a thread (e.g. nylon) to the clamp, and hang the 100 g holder for the slotted masses on it.

6. Using the ruler, measure the starting position of the bottom of the slotted masses. Record this reading.

7. Put on another 100 g mass, and measure the new position of the masses. Record this reading and calculate the extension.

8. Continue to add 100 g masses until the thread breaks or until you reach 1000 g.

9. Repeat for all the threads you want to investigate.



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FIBRES AND FABRICS:

DO ALL THREADS STRETCH THE SAME AMOUNT?

Task B Analysing the results

10. Draw a line graph of your results. You can put all your results on one axis.

11. Draw a line of best fit for each thread.

12. Which thread broke most easily? Calculate the maximum force or load that the thread could withstand before breaking by using the following equation:

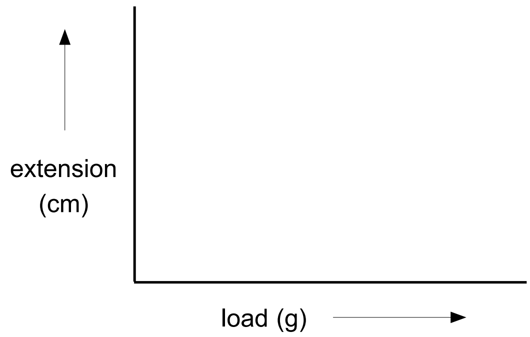
force or load (N) = mass (kg) x 10 (N/kg)

13. Look at the slopes of the lines on the graph. Which thread stretched most easily?

14. Are the lines on the graph straight or curved? If the gradient on the graph changes from a straight line to a curve then what is happening to the thread?

15. Write a list of the threads from most elastic to least elastic.

16. Compare your conclusions with other groups. Are these results reliable? Could you improve the method?



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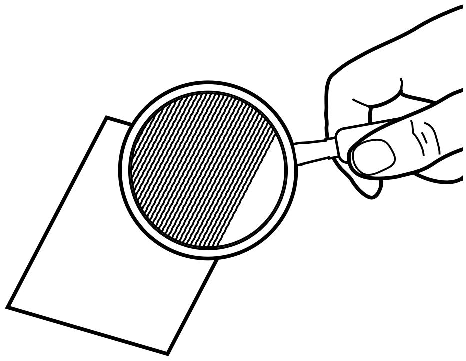
FIBRES AND FABRICS:
WATERPROOF NATURE OF FABRICS

Some fabrics have holes or pores in them. These holes allow air to be trapped in the fabric making it a good insulator. But water can easily soak into a fabric, and this makes it heavy. The person wearing it will feel cold, since their body loses heat as the water evaporates – similar to how your body cools itself by sweating.

Task A Making a prediction

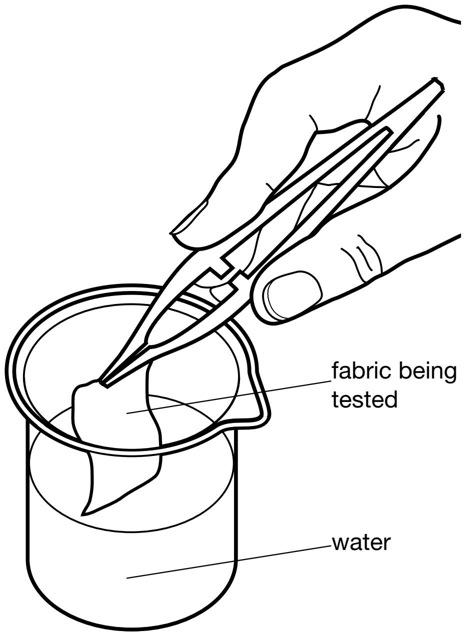


1. Use a hand lens to look carefully at your samples of fabric. Which fabrics have pores? Which fabrics do you think will be waterproof?

Task B Testing the fabrics

2. Draw a suitable table for your results.

Fabric	Starting mass (g)	Final mass (g)	Change in mass (g)



3. Using an electronic balance, measure the mass of a fabric sample. Record the measurement in your table.
4. Put the sample into a beaker of water and stir it for about half a minute.
5. Remove the sample and allow the excess water to drain from it. Measure the new mass of the sample.
6. Repeat for the other samples of fabric.
7. Which fabric(s) were most waterproof?

Task C Evaluation

8. Look back at your prediction. Was your prediction correct?
9. Was your experiment a fair test?
10. How could your experiment be improved?

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FIBRES AND FABRICS:
HOW ARE FABRICS MADE WATERPROOF?

Once a use has been identified, the choice of a fabric depends on its properties. Sometimes its properties can be changed using chemical treatments and different methods of manufacture to make the fabric more suitable for the job.

In this research task, you can use textbooks, websites or *Resource R1: Fact sheets on fibres and fabrics.*

Task A Research

1. Fabrics can be natural or synthetic (man-made). Identify a range of waterproof fabrics and using a table, categorise them as natural or synthetic.

Natural fabric	Synthetic fabric

2. Find out about Teflon. Is it always waterproof?

3. Using a diagram, explain how Gore-Tex has been designed to be waterproof but breathable.

4. Write a list of chemical coatings that can be used to make natural fabrics, such as linen, waterproof.

Task B Writing an article

5. Write an article for a GCSE revision magazine about waterproof clothing. Your article should include uses of waterproof clothes, examples of waterproof materials and explanations as to how they remain waterproof.

Task C Peer review

6. Give your article to another group of students. Ask them to write comments on the presentation, suitability of language and science content. (They could use the school marking policy.)

7. Look carefully at what the students in the group have written. Now add your own comment addressing what they have said, including a way that you think you could improve your article.

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FIBRES AND FABRICS:
HOW WELL DO DIFFERENT FABRICS INSULATE?

Some fabrics are good insulators. This means that they trap thermal energy and keep you warm. Some fabrics are 'smart materials' that have been designed to spread thermal energy evenly through the fabric to allow the wearer to feel more comfortable.

In this task you are going to compare the insulation properties of different fabrics. There are two methods to try out and to compare.

⚠ *The hotplate starts to heat up as soon as it is connected to the power supply. It can get very hot and will stay hot for some time after it is disconnected. Do not touch the hotplate while it is hot.*

Task A
Using an infrared thermometer and hotplate (method 1)

1. Set the mini-hotplate to 50 °C. You are going to time how long different samples take to warm up.

2. Draw a suitable table for your results.

Fabric	Time (s)			
	Run 1	Run 2	Run 3	Mean
Cotton				
Nylon				
Linen				

3. Put a piece of fabric on to the hot plate. Using the infrared thermometer, record the time that it takes for the fabric to reach 40 °C.

4. Remove the fabric and let it cool. Repeat the procedure twice more.

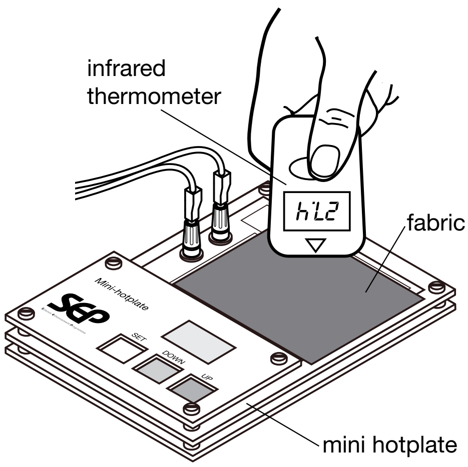
5. Calculate the mean time for the fabric to reach 40 °C:

mean time = (time 1 + time 2 + time 3) / 3

6. Repeat for the other fabrics.

7. Draw a bar chart to show the time it takes for each fabric to reach 40 °C. (Why is a bar graph better than a line graph here?)

8. Which fabric was the best insulator? How can you tell?



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FIBRES AND FABRICS:

HOW WELL DO DIFFERENT FABRICS INSULATE?

Task B
Using hot water in a flask (method 2)

9. Get three 250 cm^3 glass conical flasks and wrap each in a different fabric. Hold the fabric tightly around each flask using a piece of sticky tape.

10. Put a -10 °C to 110 °C thermometer into each conical flask.

11. Draw a suitable table for your results.

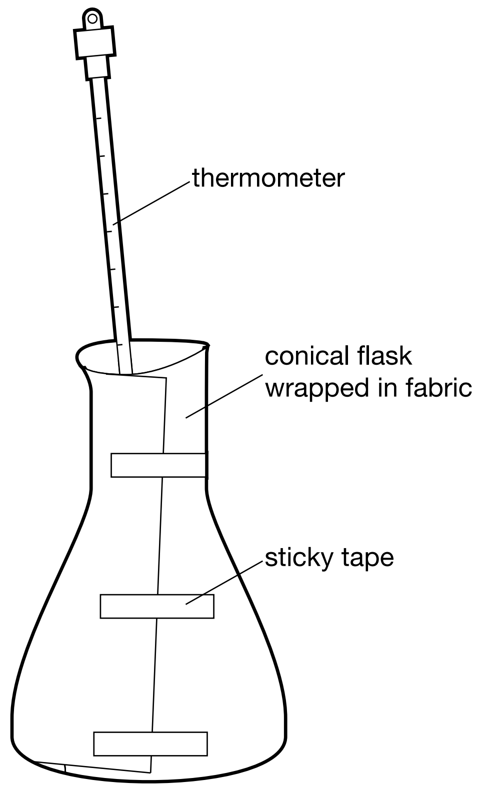
Time (minutes)	Temperature (°C)		
	Cotton	Nylon	Linen
0			
0.5			
1.0			
1.5			

12. Using a measuring cyclinder, put 100 cm^3 of hot water from a kettle into each conical flask.

13. Take the temperature of the water in each conical flask every half minute for 15 minutes. Record the data into your table.

14. Draw a line graph to show the temperature change for each type of fabric on the same axis.

15. Which fabric was the best insulator? How can you tell?



Task C
Evaluation of the two methods

16. Compare the results for the two different methods. Did you get the same results? Are your results reliable? Are your results accurate?

17. Compare the two different methods. Which do you think is better and why? How could you further improve this method to get better results?

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FIBRES AND FABRICS:
WHAT IS THE HISTORY OF FABRIC DYEING?

The colour of fibres and fabrics can be changed using dyes. Dyes can come from natural sources (such as roots, flowers or berries) or be synthetic (the first was mauveine in the 19th century). Dye molecules may be chemically attracted to the fibres directly; often a special chemical called a mordant is used which can help a dye stick to a fabric and stop it from washing out.

In this research task, you can use textbooks, websites or *Resource R1: Fact sheets on fibres and fabrics.*

Task A Research

1. Find out about different dyeing techniques. Draw a table to write the date the technique was invented and whether the dye is natural or synthetic.

2. Make a note of your sources of information. Are they primary or secondary sources?

Primary sources of information are when the data is collected first-hand. Secondary sources of information are when the data is collected from the media or other people's primary sources.

Date	Technique	Natural/synthetic

Task B Making a timeline

3. Make a timeline to show how the dyeing of fabric has changed over the years. Explain how two natural and two synthetic dyes are made, and include brief information of five other dyeing methods.

4. Look carefully at your timeline. How has the range of colours changed over time? How has the ratio of natural to synthetic dyes changed over time?

Task C Peer review

5. Look carefully at the timelines of two other students. Add a new piece of information from their work onto your timeline.

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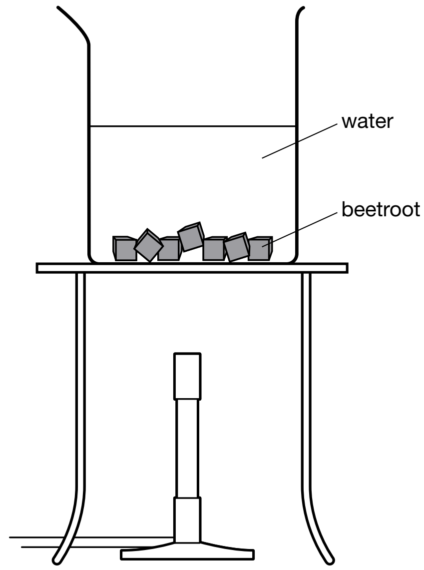
FIBRES AND FABRICS:
MAKING NATURAL DYES

Many plants can be used to make dyes. The coloured materials can be extracted and then used to dye fabrics or fibres. Some dyes are colourfast and can be washed many times without fading. Other dyes need a mordant, a special chemical that helps it to stick to the fibres and makes the dye colourfast.

In this activity, you will make your own natural dye and test it to see how colourfast it is.



Task A Making the natural dye

1. Half fill a 250 cm^3 glass beaker with chopped beetroot. Using a measuring cylinder add 100 cm^3 of water.

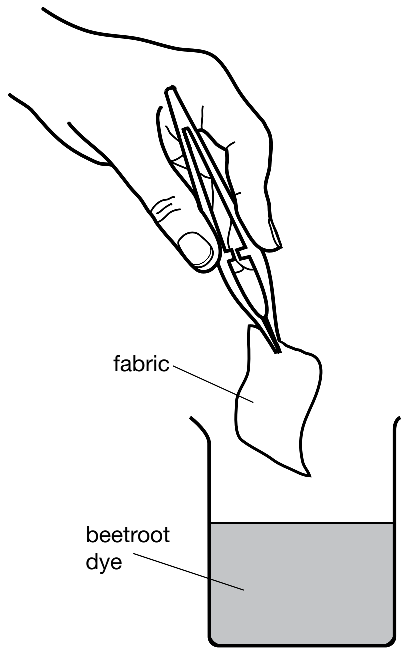
You may wish to make other natural dyes – for example, you could use onion skin or red cabbage.

2. Boil the mixture for 20 minutes. Remove from the heat and allow it to cool.

3. Flute a piece of filter paper and put into a filter funnel. Rest the filter funnel in the neck of a 250 cm^3 conical flask.

Why is it best to flute the filter paper rather than just fold it twice to fit into the filter funnel?

4. Filter the cooled mixture and keep the filtrate (liquid). You may dispose of the filter paper and beetroot.



Task B Dyeing the fabric

5. Transfer your natural dye to a 250 cm^3 glass beaker.

6. Cut up samples of different fabrics so that they are all the same size.

7. Put the samples into the dye for about a minute, and stir with a glass rod.

8. Using tongs, remove the samples from the dye and allow to dry.

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FIBRES AND FABRICS:

MAKING NATURAL DYES

Task C Testing the dye

9. Draw a results table in which you can stick samples of your raw (undyed) and dyed fabrics.

	Cotton	Nylon	
Undyed			
Dyed with beetroot			

10. Look carefully at your dyed fabrics. Which fabric took up the dye the best?

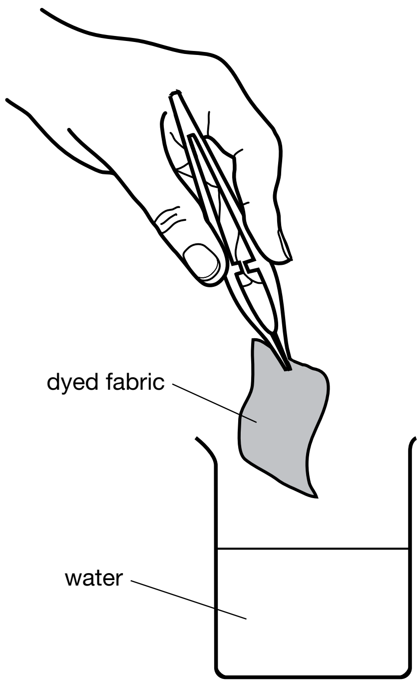
11. How well is the dye is absorbed by natural fabrics compared to synthetic or man-made fabrics? Is there a correlation (or pattern)?

12. How could you test whether your natural dye is colourfast?

Remember that sometimes a fabric can just get wet and the colour runs. Other times, the fabric could be colourfast in water but when washed with a detergent the colour runs or fades. This is when fabric can only be dry-cleaned.

13. Test if your fabrics are colourfast.

14. Does the fabric make a difference to how colourfast the dye is?



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FIBRES AND FABRICS: THERMOCHROMIC PIGMENTS

Thermochromic pigment is a smart material. The colour of the pigment changes as the temperature changes. So, the *stimulus* for this smart material is the *temperature*.

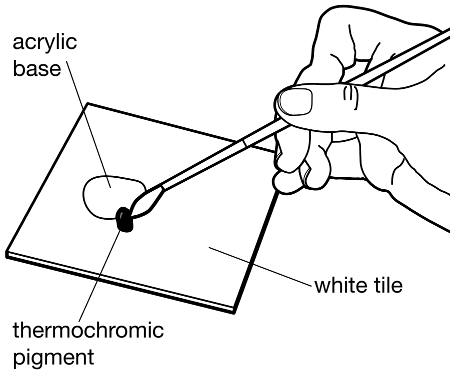
The *transition temperature* is the temperature at which there is a change in the pigment particles resulting in a colour change.

In this task you are going to find out the transition temperature of a thermochromic pigment.

⚠ *The thermochromic pigment is an irritant. Avoid skin contact. Wear disposable gloves and eye protection when handling the pigment.*

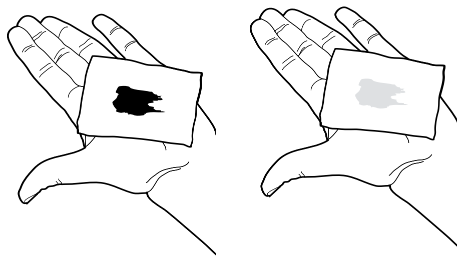
Task A Making thermochromic paint and preparing the fabric

1. On a white tile, squeeze a pea-sized amount of the white acrylic base.
2. There are different colours of thermochromic pigment. Choose which one you want to use, and squeeze half a pea-sized amount onto the acrylic base.
3. Using a paint brush, carefully mix the pigment and the acrylic base to make a ‘thermochromic paint’.
4. Choose a fabric that you want to investigate. Make a note of the fabric that you have chosen.
5. Using the paintbrush, carefully coat a small area of the fabric sample with thermochromic paint.
6. Leave the fabric in a warm place overnight until the paint has cured (dried).



Task B Testing the fabric

7. After the fabric has dried, hold it between your hands to warm it. What happens to the colour? Leave it to cool. What happens to the colour?



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FIBRES AND FABRICS:

THERMOCHROMIC PIGMENTS

Task C Finding the transition temperature

You will now warm up the fabric sample slowly, measuring its temperature, and noting when the colour changes.

8. Draw a suitable table for your results.

Time (s)	Temperature (°C)	Colour
0		
15		
30		
45		

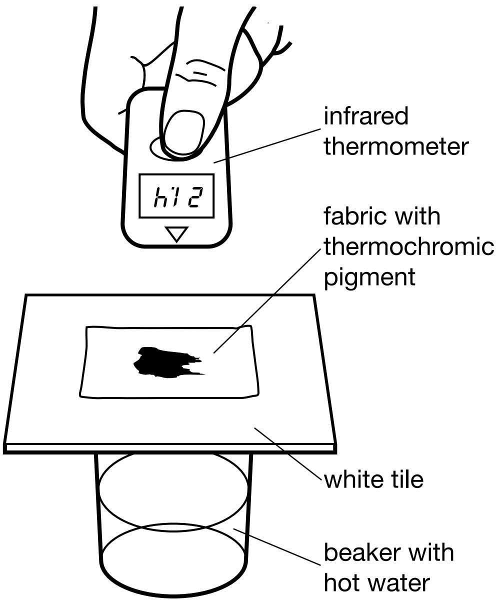
9. Put your painted fabric onto a white tile that has been cooled in the freezer.

10. Add about 100 cm^3 boiling water to a 250 cm^3 glass beaker and gently balance the white tile on it.

11. Using the infrared thermometer, take the temperature of the fabric and note the colour every 15 seconds until no more colour changes are seen.

12. Look carefully at your results. Between which two temperatures did the transition of the thermochromic pigment happen?

13. Could you improve this method? How could you find the exact transition temperature?



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FIBRES AND FABRICS: PHOSPHORESCENT PIGMENTS

Phosphorescent pigment is activated by UV light and then emits lower frequency light – in the dark you can see it glowing brightly. So, it stores the energy from the UV light and then releases it.

In this activity, you are going to find out how the time of exposure and the source of light affects the amount of phosphorescence.

The phosphorescent pigment is an irritant. Avoid skin contact. Wear disposable gloves and eye protection when handling the pigment.

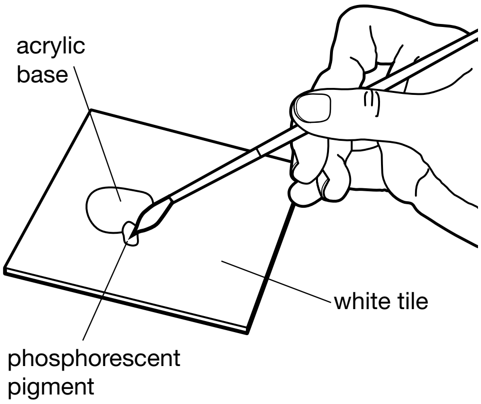
Task A Making the phosphorescent paint

1. On a white tile, squeeze a pea sized amount of the white acrylic base.

2. Add half a microspatula of phosphorescent pigment powder.

3. Using a paint brush, carefully mix the pigment and the acrylic base.

If you think the mixture is too thick to paint onto a fabric, use a dropping pipette to add drops of water. Make sure that you mix the water throughly, until you get the thickness of paint that you want.



Task B Preparing the fabric

4. Choose a fabric that you want to investigate. Make a note of the fabric that you have chosen.

5. Using the paintbrush, carefully paint the phosphorescent paint onto a sample of the fabric.

6. Leave the fabric in a warm, dark place, overnight until the paint has cured (dried) and does not phosphoresce (glow).

Task C Observing phosphorescence

7. Take out your prepared fabric and hold it next to the window for 1 minute. Now switch off all the lights. What do you notice?

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FIBRES AND FABRICS:

PHOSPHORESCENT PIGMENTS

Task D Investigating phosphorescent film

In this task, you are going to use phosphorescent film (glow-in-the-dark film), rather than the fabric sample that you have prepared.

8. First, investigate the effects of different exposure times.

In a darkened room, hold a torch about 20 cm from the film. Switch the torch on for about 10 seconds. Switch the torch off and observe what happens to the film.

Repeat with the torch switched on for about 30 seconds.

What do you notice? Is there a relationship between the phosphorescence and the time a light source is on for?

9. Now compare the effects of different intensities of light.

Hold a torch about 20 cm from the film and switch on for 30 seconds.

Repeat with the torch held about 50 cm from the film.

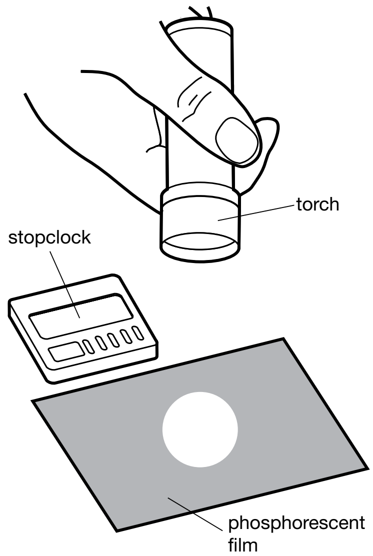
What do you notice? Is there a relationship between the phosphorescence and the intensity of the light source?

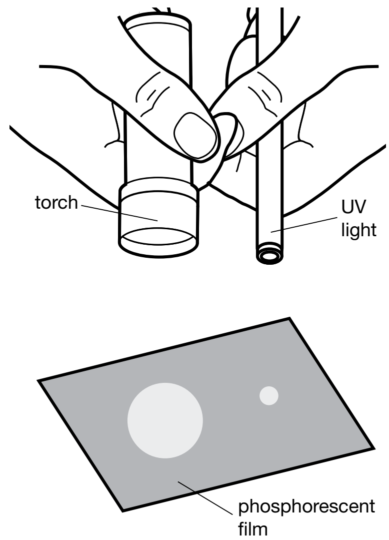
10. Next, compare the effects of different kinds of light.

Use a torch and an 'ultraviolet pen'. Hold each one about 10 cm from the film, pointing at different places on the film. Switch each one on for about 10 seconds.

What do you notice? Is there a relationship between the phosphorescence and the kind of radiation that was used to energise the film?

Do not look at the UV LED. Wear UV filtering eye protection





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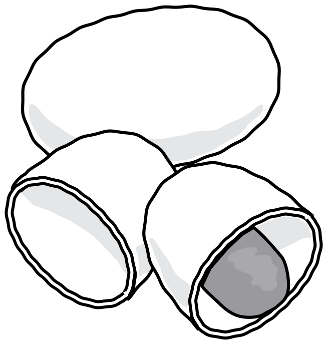
FIBRES AND FABRICS:
WHERE DOES SILK COME FROM?

Silk is a natural fibre made of protein that is obtained from the cocoon of a silkworm. Once the worm has made its cocoon, it is heat treated to kill it. Up to a kilometre of silk fibre can then be unwound from each cocoon.

In this activity your teacher will show you how to get silk from a silkworm cocoon.



Task A Studying the cocoon

1. Your teacher will pass around a silkworm cocoon. Describe what it looks and feels like.
2. Your teacher will now cut the cocoon in half. What is inside? How does the inside of the cocoon compare to the outside?

Task B Getting the silk threads

3. Your teacher will have soaked a cocoon in soapy water. They will then find a fibre and begin to pull.
4. What happens?
5. How do you think silk threads can be made from silk fibres?

Task C Researching different types of silk

6. Spiders also make a type of silk called gossamer. Make a table to compare and contrast silk from spiders with that from a silkworm.

	Type of silk	
	Silkworm	Spider
Composition		
Use by animal		
Use by humans		

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FIBRES AND FABRICS: SOAP AND DETERGENT

Natural fibres often have to be cleaned to remove natural impurities before they can be made into fabrics. Fabrics also need to be cleaned when they get dirty.

In this activity you are going to make a poster to explain how fabrics can be washed and the differences between soap and detergent. In this research task, you can use textbooks, websites or Resource *R1: Fact sheets on fibres and fabrics.*

Task A Research

1. Find the definitions of:
- Soap
- Detergent
- Dry-cleaning

2. Find out the differences between soap and detergent, and fill in the table.

	Soap	Detergent
How is it made?		
An example		
Behaviour in hard water		
Behaviour in soft water		
Environmental impact		

Task B Making a poster

3. Make an A4 poster to explain how water, soap, detergent and dry cleaning can be used to clean fabrics.

Your poster should be aimed at GCSE students and be attractive to encourage them to read it. Include at least one labelled diagram, and the key words: saponification, soap, detergent, surfactant and solvent.

Task C Peer review

4. Give your poster to four other students. Ask them to check that you have fulfilled the brief in Task B, and to write comments on the presentation and science content. (They could use the school marking policy.)

5. Look carefully at what they have written. Now add your own comment addressing what they have said, including a way that you think your work could be improved.

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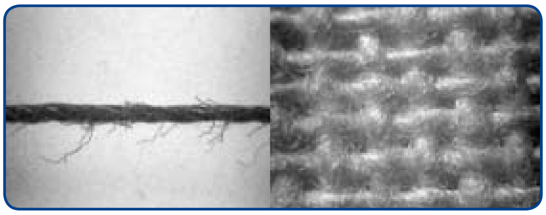
FIBRES AND FABRICS
FACT SHEETS

Cotton

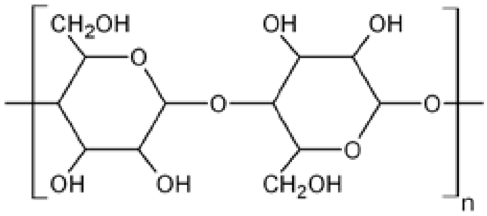
Cotton is a natural fibre made from a plant (Gossypium) native to subtropical regions like India. The fibre grows around the cotton seeds. It is collected, treated and used to make a soft, breathable fabric. The fabric is flammable and can biodegrade easily, but these properties can be modified with chemical treatments.

This fabric is a natural polymer that consists of almost pure cellulose. Each cotton fibre is made of up to thirty layers of cellulose arranged in springs. The cotton boll is opened and allowed to dry. The fibres become ribbon like shapes and can easily be turned into yarn.

Cotton has many uses including clothes, thread and medical supplies.



cotton thread (x10) *cotton fabric (x10)*

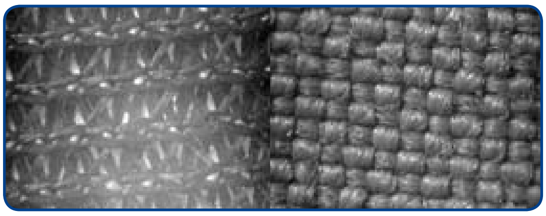


Gore-Tex

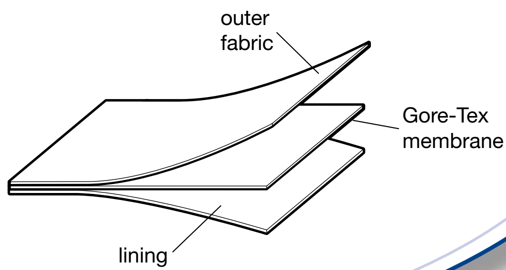
Gore-Tex™ is a material made by W. L. Gore & Associates. It is a fabric consisting of layers of other materials, including a Gore-Tex membrane made of polytetrafluorethene (Teflon™). All of the layers in this fabric are synthetic (man-made).

The fabric keeps water out but the membrane has small pores that allow sweat to escape. This makes the fabric waterproof but breathable.

This composite material has many uses that include mountaineering clothing, electrical cable insulation and the fabric for tents.



Gore-Tex outer fabric, double layer (x10) *Gore-Tex outer fabric, triple layer (x10)*



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FIBRES AND FABRICS

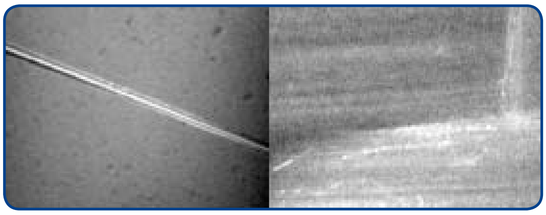
FACT SHEETS

Kevlar

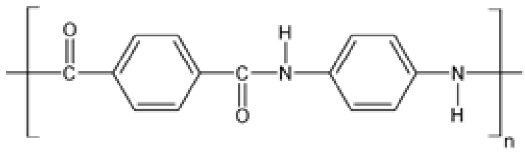
Kevlar™ is a man-made or synthetic fibre. It is a co-polymer (plastic), made from two starting chemicals (1,4-phenylene-diamine and terephthaloyl chloride).

The material was first made by DuPont in the 1960s. It is lightweight and strong over a range of temperatures.

This material has many uses which include bullet-proof vests, brake discs and a protective cover for fibre optic cable.



Kevlar fibre (x10) *Kevlar fabric (x10)*



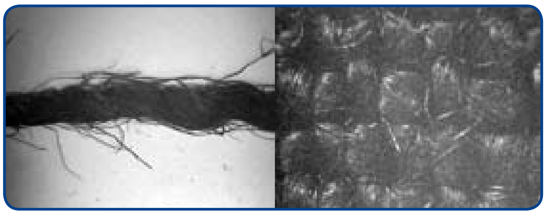
Linen

Linen is a natural fabric made from a plant fibre (Flax). Flax is native from the eastern Mediterranean to India.

The flax fibre is extracted from the stem of the plant and is the strongest of the vegetable fibres. The fibres can be from 25 to 150 m long and 12-16 μm wide. A cross-section of the fibre shows irregular polygonal shapes which when woven into linen, gives the coarse texture of the fabric.

Linen is highly absorbent and a good conductor of heat, making the fabric feel cool to touch.

This fabric has many uses including clothes, wallpaper and canvass.



linen thread (x10) *linen fabric (x10)*

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FIBRES AND FABRICS

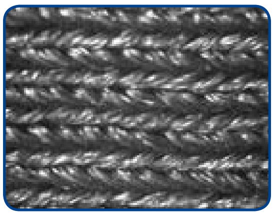
FACT SHEETS

Lycra

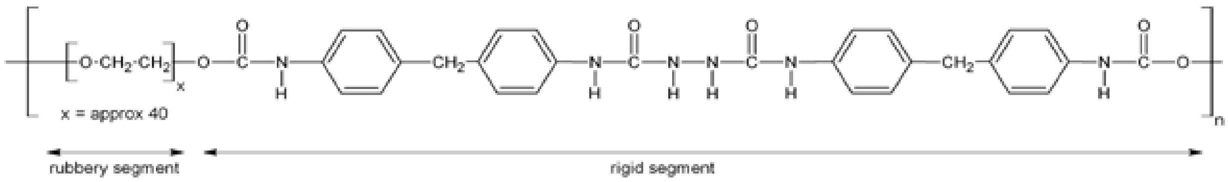
Lycra® is a synthetic or man-made fibre. It is a co-polymer (plastic) made from two different starting chemicals (urethane and ethylene glycol).

The elastic polymer was invented in the 1950s by DuPont and is marketed under a variety of names including Spandex. It is lightweight, resistant to sweat, sun and abrasion.

The material has many uses which includes elastic sports clothing wetsuits, and medical support stockings.



Lycra fabric (x10)

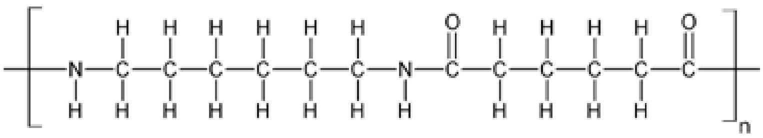


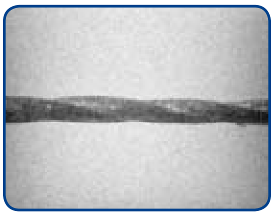
Nylon

Nylon is a man-made or synthetic co-polymer polymer (a plastic made from two starting chemicals or monomers). It is made by reacting a dicarboxylic acid with a diamine, to form an amide linkage.

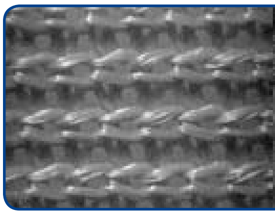
Polyamides such as nylon are thermoplastic. Nylon does not absorb water easily, it is easily dyed and is a good electrical insulator.

Nylon can be made into a silk replacement, but has many other uses including toothbrush heads, carpets and clothing.

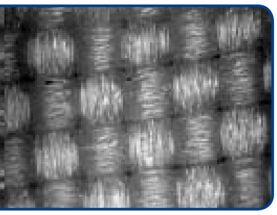




nylon thread (x10)



nylon fabric (x25)



ripstop nylon fabric (x25)

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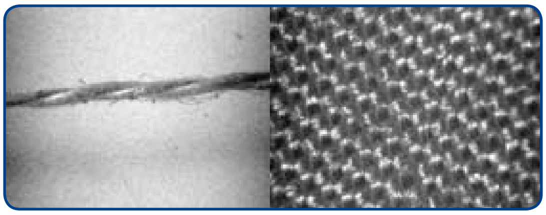
FIBRES AND FABRICS

FACT SHEETS

Silk

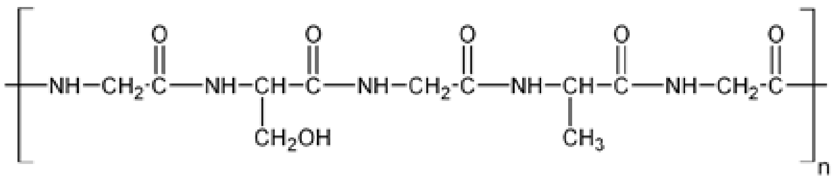
Silk is a natural fibre made from the cocoon of the silkworm (Bombyx mori). Silkworms are farmed and their cocoons collected. The cocoon is heated to kill the worm and then unwound, releasing up to 1 kilometre of natural protein fibre that can then be spun into silk fabric.



silk thread (x10) *silk fabric (x10)*

The natural silk fibre has a natural shine, and a soft, smooth texture. It is a strong fibre, but sunlight weakens it. Silk absorbs water easily. It is a thermal and electrical insulator and causes a lot of static electricity to build on its surface.

Silk has many uses including clothing, parachutes, bicycle tyres and non-absorbent surgical thread.

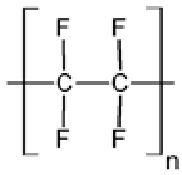


Teflon (PTFE)

Teflon® has the chemical name polytetrafluoroethene and is a man-made or synthetic fibre. It is a polymer (plastic), first made in 1930s by DuPont.

This material has a high melting point, resistant to chemical attack and has can be used to make non-stick coating.

PTFE has many uses including cookware, stain-resistant clothing and artificial hips.



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FIBRES AND FABRICS

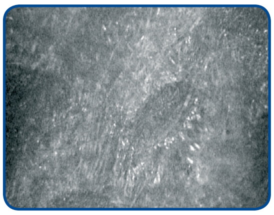
FACT SHEETS

Thinsulate

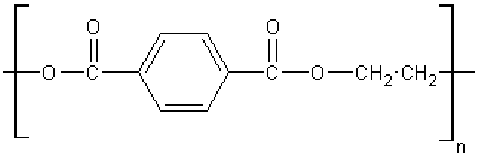
Thinsulate™ is a synthetic fabric made from a mixture of two polymers (plastics) – poly(ethylene terephthalate) and polypropene. Different types of Thinsulate have differing proportions of each polymer depending on their applications. The polymers are spun into fibres that have a thickness of about 15 µm. These are then used to make the fabric.

Thinsulate™ is a smart material, made by 3M and first sold in 1980s. It is a good thermal insulator, but allows moisture to escape and is lightweight.

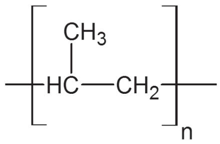
This fabric is mainly used for winter clothing.



Thinsulate surface (x10)



poly(ethylene terephthalate)



polypropene

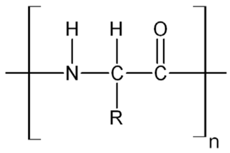
Wool

Wool is a natural fibre made from the hair of mammals such as sheep and goats.

The animal is sheared (shaved), and the fur is washed to remove the dirt and grease. The grease is called lanolin and can be used to make many things including shoe polish and cosmetics. The fur can be chemically treated with alkali and detergents, and the fleece used to make yarn.

Wool is a good insulator of heat, absorbs water well and is elastic. Wool does not catch light easily and often self-extinguishes if it does catch fire.

This natural fibre has many uses including firefighter's clothes, felt and building insulation.



R = H, CH_3 or CH_2OH

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FIBRES AND FABRICS:
GLOSSARY OF TECHNICAL TERMS

Word	Definition
Colourfast	The dye does not come out of the fabric when it is washed in water.
Conductor	Allows heat and/or electricity to pass easily through it.
Detergent	Synthetic washing agent, similar to soap, but not made from fat.
Dye	A substance used for staining or colouring. They are often soluble in water.
Elastic limit	The amount of load a material can support before it permanently changes shape or breaks.
Fabric	A material made by weaving, knitting, crocheting or felting fibres.
Fibre	A long thin material that can be wound into a thread.
Hooke's Law	This states that the extension of a material is proportional to the load until the elastic limit is reached.
Insulator	Does not allow heat and/or electricity to pass easily.
Man-made fibre	A fibre made from a chemical reaction.
Mordant	A chemical that helps dyes and/or pigments stick to fibres.
Natural fibre	A fibre made directly from a plant or an animal.
Phosphorescent pigment	A pigment that is activated by UV light and will then glow.
Pigment	A coloured material, but unlike a dye, a pigment is insoluble in water.
Plastic deformation	Permanently changing shape.
Pores	Small holes.
Property	A characteristic of something.
Saponification	The chemical reaction used to make soap.
Smart material	A material whose properties change in a particular way as its environment changes.
Soap	A chemical used for cleaning, made by the reaction between fat and sodium hydroxide.
SOCO	Scene of Crime Officer
Stimulus	A change in the environment to which a smart material is sensitive.
Synthetic fibre	A fibre made by a chemical reaction.
Thermochromic pigment	A smart pigment that changes colour as the temperature changes.
Thread	Fibres that have been wound together to make them stronger and more useful.
Transition temperature	The temperature at which a change happens.

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BACKGROUND SCIENCE

This section gives further information about some specialist fabrics, and how fabrics can be treated with dyes and mordants.

SOME SPECIALIST FABRICS

Gore-Tex

Gore-Tex™ is a composite fabric which is breathable and waterproof. This is because one of the layers of the composite is a polymer membrane made of polytetrafluoroethene (PTFE) that contains over a billion microscopic pores per square centimetre. Liquid water droplets are about 20,000 larger than these pores and therefore cannot penetrate the PTFE membrane; however, water molecules are about 700 times smaller than the pores and so evaporated sweat is able to pass through. Gore-Tex was originally designed for waterproof macintoshes that would be more comfortable to wear since they would not allow rain to pass, but would avoid the build up of sweat inside the coat. One variety of Gore-Tex consists of just two layers, the outer one being made of a fabric such as nylon or polyester, and the inner one of the PTFE membrane. The inner layer may have a tendency to become worn or damaged, and to reduce this, three-layer Gore-Tex includes an inner lining to protect the membrane.

Kevlar

Kevlar™ contains long polymer chains consisting of aromatic rings joined together by amide groups. It is made by the polymerisation of two monomers – 1,4-phenylene-diamine and terephthaloyl chloride – and is thus a condensation co-polymer (see the formula on page 46). The long molecular chains are relatively rigid and line up alongside each other as sheets, with extensive hydrogen bonding between the chains (the oxygen atoms in C=O bonding to the hydrogen atoms in N-H). It is this highly ordered nature that results in its great strength in comparison to other polymers. The molecules of polymers such as nylon and polyester are flexible, and when the solid is formed these molecules are highly entangled; drawing fibres from these can produce some greater orientation of the molecules, but very far from the almost perfect crystalline packing in Kevlar. Being a polymer, Kevlar is also relatively lightweight, and its strength-to-weight ratio is considerably greater than that of steel. Indeed, its first commercial use was as a replacement for steel in racing tyres.

Lycra

Lycra® is also known by its generic name of 'spandex' (derived from the word 'expand'). It is made from relatively complex polymer molecules and it is these that give Lycra its special properties (see the formula on page 47). Like rubber, it is highly elastic, but is stronger and lasts longer. The molecule consists of alternating soft rubbery segments and rigid segments. The rubbery segments consist of chains of about 40 glycol units, which are flexible and coiled, and will stretch when a force is applied to them. In between, the rigid segments consist of aromatic rings joined by urethane and urea linkages (-NH-COO- and –NH-CO-NH-). These rigid segments hydrogen bond to the corresponding segments of other molecules forming stiff blocks that are linked together by the rubbery soft sections to form an elastic fibre. Lycra can be used as a single fibre, or fibres can be fused together at intervals to for a multifilament yarn.

Thinsulate

Thinsulate™ is a very lightweight insulating material made from polymer fibres - mainly mixtures of polypropylene and poly(ethylene terephthalate). The material is manufactured in such a way that there are many tiny air pockets within the fabric. This means that it is a good thermal insulator as it reduces the loss of thermal energy through convection and conduction. The material also reflects radiated energy back to the wearer, again reducing the amount of heat loss. Insulation normally used in clothing is made from polyester fibres, and these are around 10 times thicker than the fibres used in Thinsulate. The thinner fibres in Thinsulate (around 5 – 10 μm in diameter) enable a greater fibre density to be achieved and this increases it insulating properties.

DYES AND MORDANTS

The colours of fabrics can be changed by using dyes. Typically a dye is a coloured substance that is soluble in water, and whose molecules are attracted in some way to the molecules of the fibre. Different dyes are therefore more or less effective for different fabrics depending on the chemical nature of each. This distinguishes a dye from a pigment, which is insoluble in the medium or 'binder' in which it is used; for example, an emulsion paint contains a pigment and a binder, and it is the binder that holds the pigment to the surface being painted.

A dye molecule contains a chromophore, which is the active part of the molecule responsible for creating the colour. The chromophore absorbs light of a particular frequency as an electron is promoted from the ground state to an excited state. Chromophores contain either conjugated systems of unsaturated bonds or metal complexes – it is these that have differences in energy levels that correspond to electromagnetic radiation in the visible region. Organic chemists can choose different functional groups to add to the chromophore to change its colour, to modify the properties of the dye so that it is more soluble in a specific solvent, or to increase the colourfastness.

Many dyes need a mordant, or fixative to allow the dye molecules to attach to the fibre. For example, historically the alum industry grew in Yorkshire to supply the mordant for the wool dyeing industry. A mordant must be chosen to suit the fabric and the dye being used. Mordants include tannic acid, alum, sodium chloride and other metal salts. The mordant can either be absorbed by the fabric before it is dyed, mixed with the dye itself, or the fabric can be dyed first and then treated with the mordant. Each of the different methods produces a different shade of the dye and can affect the fastness. Also the same mordant and dye can produce different shades on different fabrics.

Cotton fibres only loosely hold mordants and they must be precipitated onto the fibres before dyeing. Wool often makes colourfast fabrics because it can absorb fine precipitate from solutions. The dye reacts with the precipitates and the dye is therefore clinging to the surface of the wool fibre. However, when the material is rubbed, the colour will come off too. As wool is amphoteric (behaves as both an acid and base) it is highly attracted to mordants. When a metallic mordant is used, the mordant is hydrolysed to produce a basic component that is absorbed into the –COOH group on the wool fibre. The acidic component is then removed when the fibre is washed in water.

REFERENCES AND FURTHER READING

Websites

Additional resources can be found on the SEP website (see page 54). Links to other particularly relevant websites are also listed on the SEP website. Some examples are given below:

Wikipedia (http://en.wikipedia.org)
There are specific sections about each natural and synthetic fibre featured in this booklet. These articles contain information about how they are made and used, their properties and interesting historical context.

Crystal Palace Yarns (www.straw.com/sig/dyehist.html)
This company specialises supplying fashion and classic yarns. It contains a timeline which shows the major developments in dyeing.

Colour Museum (www.colour-experience.org)
This online museum about colour has been produced by the Society of Dyers and Colourists. It contains information about how dyes can be made and used to colour fibres and fabrics.

English Heritage (www.english-heritage.org.uk)
This website includes a section about the *North-East Alum Industry* and its influence on the dyeing of fabrics.

Royal Society of Chemistry (www.rsc.org)
There is a great deal of useful and accessible information on this site, including experimental instructions on making nylon.

Practical chemistry (www.practicalchemistry.org)
A very useful website which has a collection of chemical experiments linked to the curriculum. It includes information for students, teachers and technicians for making rayon.

SOURCES

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DOWNLOADING RESOURCES FROM THE SEP WEBSITE

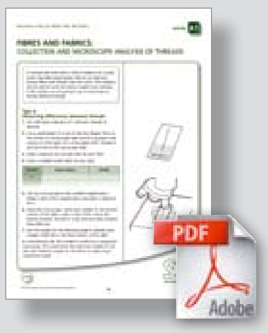
SEP produces a range of digital resources to accompany each of its publications. These are available from the 'SEP Associates' area of the website (www.sep.org.uk).

Membership of SEP Associates is free to all science teachers and technicians in UK schools. To join, fill in the online form on the website. SEP is wholly funded by the Gatsby Charitable Foundation, and joining SEP Associates entitles its members to additional benefits, including offers of free publications and other resources.

www.sep.org.uk

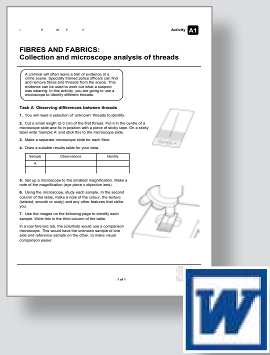
PDF file of booklet

On the SEP website there is a downloadable PDF file of the whole booklet that can be printed or viewed on screen.



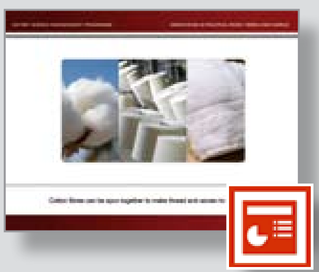
PDF files of student sheets

In addition to the whole booklet, the student activities are available as separate PDF files.



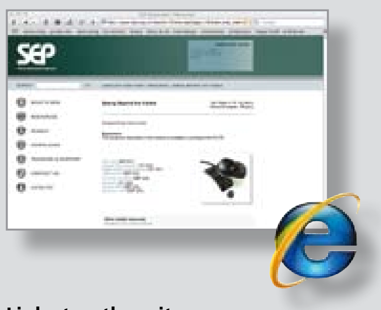
Word files of student sheets

Each student sheet also exists as a Word file. These files can be edited in order to adapt the activities to suit individual circumstances.



PowerPoint presentations

These contain the photographs and drawings shown in this booklet. They can be used to create custom-made presentations.



Links to other sites

The SEP website provides links to other useful websites on this topic.

MUTR.co.uk
in association with Middlesex University

OBTAINING THE PRACTICAL RESOURCES

SEP works in close partnership with Middlesex University Teaching Resources (MUTR) in identifying and developing low-cost practical resources to accompany its publications. Many other resources for school science and technology can also be purchased from MUTR.

The latest prices of the products shown below and further information can be obtained from www.mutr.co.uk, or by requesting their latest catalogue. Orders can be made by post, telephone, fax or email by providing an official school order number or by credit card.

Fabrics sample pack
314-154
Contains a selection of different swatches of traditional and modern fabrics.

Threads testing pack
314-155
Reels of cotton, silk, polyester and nylon for testing strength and elasticity.

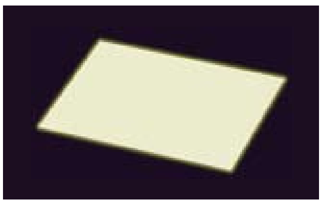
Silk cocoon
233-149A
A silk cocoon with the worm in the centre. Silk fibre can be pulled from the cocoon.

SEP Mini-hotplate
SEP 091
Thermostatically controlled hotplate up to 80 °C For use with a regulated low-voltage power supply (12V 2A).

Infrared thermometer
161-300
Point and click thermometer reading in centigrade (precision 0.1 degrees).

Smart colours starter pack
IT9 010
A set of thermochromic and photophorescent pigments with an acrylic base.

UV energiser
UV1 002
Hand held device containing UV LED (requires a separate power supply, e.g. product PS1 004).



Glow-in-the-dark film
SM1 016
A large piece of phosphorescent film with a sticky back. Easily cut with scissors.

There is a wide range of other resources useful for this topic including fabrics sold by the metre and a variety of unusual and interesting types of fibre.

You can download the written materials in this booklet, and find further information from: Science Enhancement Programme www.sep.org.uk

The Science Enhancement Programme (SEP) is part of Gatsby Technical Education Projects. It undertakes a range of activities concerned with the development of curriculum resources and with teacher education.

SEP Science Enhancement Programme

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London N14 4YZ
Email: info@sep.org.uk
Web: www.sep.org.uk

The Gatsby Charitable Foundation

You can order a range of fabrics, threads and other practical resources from Middlesex University Teaching Resources.

Middlesex University teaching resources

Teaching Resources
Middlesex University
Unit 10, The IO Centre
Lea Road, Waltham Cross
Hertfordshire EN9 1AS
Tel: 01992 716052
Fax: 01992 719474
Email: sales@muventures.co.uk
Web: www.mutr.co.uk

www.sep.org.uk

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