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SCIENCE HOTSPOTS

Natural dyes, paints and colours

What's your favourite colour for clothing, or maybe your favourite paint?
Where do they get their colours from?
What is used to make these colours for paints and dyes?
Do they come from plants, flowers, minerals – or from something else?

These stories and activities from around the world will help you to find some of the answers...I bet you're 'dyeing' to know!

Dyes in History

Throughout British history the colours used varied according to fashion and availability, so poor people often wore clothes made from cheap sources of material and dyes. Henry VIII made laws so that only the rich could wear certain colours such as silver, silk and purple. Generally speaking bright colours were restricted to the nobility until the 19th century when synthetic dyes were discovered. A lot of global travel involved a search for increasingly better dyes and better processes for dye production.

A 'Perky' Discovery

William Henry Perkin discovered the first synthetic dye in 1856. He was a science student at the Royal College of Chemistry. He was trying to make a drug from an ingredient of coal tar. The experiment produced a thick dark sludge. Instead of throwing it away, Perkin tried mixing it with alcohol and it turned purple. He discovered that this purple mixture would dye silk and that the colour did not come out of the silk during washing and it did not fade in daylight. This mixture had been seen before, but it was Perkin who realised that he could sell it in large amounts. He found customers for the new dye and, with money from his father; he set up his own dye-making company to produce the beautiful purple dye.

Until this dye was discovered, a dress dyed purple could start fading within a few hours. By 1859 the dye, now known as *mauve*, or *mauveine*, had become the height of fashion in England. Queen Victoria wore a mauve dress for her daughter's wedding in 1858 and then was given a 'Perkin's Purple' dress at the International Exhibition of 1862 in London. A set of stamps (the penny mauve) was printed in 1881 in the same colour. The success of the new dye encouraged other scientists to experiment in making more synthetic dyes.

Some useful terms

Cellulose - A major component of textile fibres like linen, cotton, paper and viscose.
Dye - Anything that colours things. They are a pigment dissolved in a solution.
Fastness - A measure of how well a dye stays in a fabric after washing. A really good dye actually chemically attaches to the molecules of the fabric and can never be washed out.
Fixing - The process that makes the dyes stick to the fabric/material.
Paints - Pigments suspended in a liquid such as oil or egg yoke so that it sticks to a surface rather than reacting with the material.
Pigment - An intensively coloured substance which can be organic such as part of a plant or animal (henna and cochineal) or inorganic such as mineral rocks (malachite gave green pigments).
Mordants - These are added to pigments and dyes to help them stick to fabric.
Synthetic - A fibre or material that is not natural and has been chemically produced.

Activity One: Plant Dyes and food colouring from around the world – which is the best?

Testing the Fastness

Background – some worldwide popular dyes

Indian people colour their food bright yellow and reds, the Spanish make the rice fish dish called Paella by flavouring and colouring it yellow with Saffron. Turmeric gives flavouring and a bright yellow colour to curries. Many cultures paint their hands with Henna during festivals and weddings. Indigo is the main dye used to colour Denim - particularly Jeans. In this investigation you will look at the dyes found in three natural dyes: Henna, saffron and turmeric.

Task

Devise an experiment to dye a piece of cotton material and test the dyed material for the fastness of the dye by using washing detergent.

You are provided with:

- Solutions of each dye
- Equal sized white cotton pieces of material
- Detergent
- School laboratory equipment

Remember, you must make sure it is a fair test and safe!

If you would like to actually undertake this activity in a practical lesson, then please get your teacher to check your plans before you start!

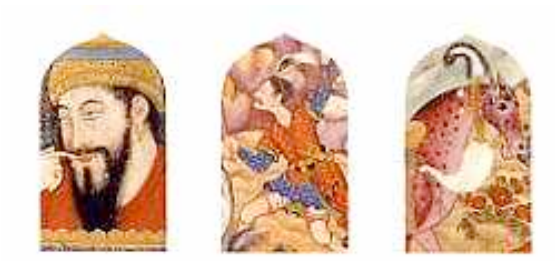
Extension Material - How do Dyes work?

Each different shape of dye molecule absorbs light differently. That is what makes the different colours. The fabric your clothing is made out of is also made of molecules. Cotton, which grows on a cotton plant, is made of long strands of cellulose molecules, all twisted together. Cellulose has a fairly open structure that allows larger molecules such as dyes to move through it and bond. Sodium carbonate, Na_2CO_3, is often added to help the cotton form charges that chemically bond with dyes rather than the dye just staining the material. It helps to make a permanent bond between the dye and the cotton. The reaction happening is that chlorine molecules are coming off the dye molecules and hydrogen molecules are coming off of the cellulose molecules. If they do this right next to each other, the dye then attaches to the cellulose, and a permanent bond is formed. After rinsing in cold water and washing it with detergent in hot water to get all the extra dye off, the dye left on the fabric is permanent.

A Case Study of Shammi Banu – an Indian Painter

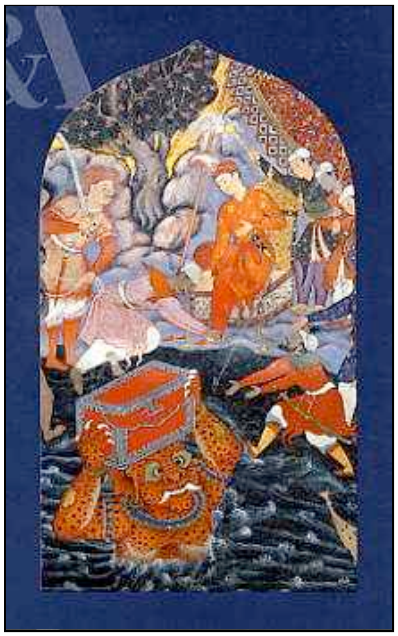
Shammi is a painter of miniatures in India and he needs to know much more about the science of his 'paints' in order to re-create techniques by his fore-fathers.....

Shammi Sharma (Shammi Bannu)



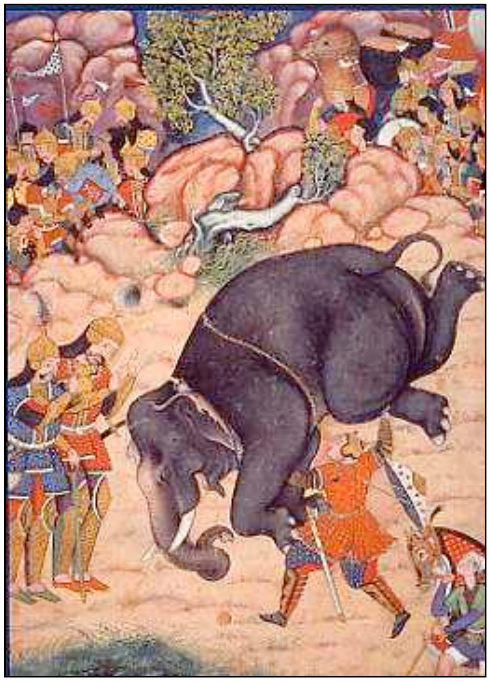
Miniatures by permission of the Victoria and Albert Museum

"My family have practiced the craft of miniature painting for over seven generations. We were the original court painters since Maharaja Sawai Jai Singh-II the founder of Jaipur. I continue to work in the traditional ways, all skills and knowledge of the craft have been passed down from my forefathers through my father Bannuji Ved Pal Sharma. He is considered the last Master of the Craft, his works in the field of restoration has been fundamental to the preservation of the craft in India. It is my duty to continue the family tradition. I have set up a studio in Jaipur with several craftsmen. Since 1997 I have taught two students from UK and USA and two Indian students. We have begun an extensive survey of the methods and material of the craft documenting the visual research that my father had carried out over the last thirty years."



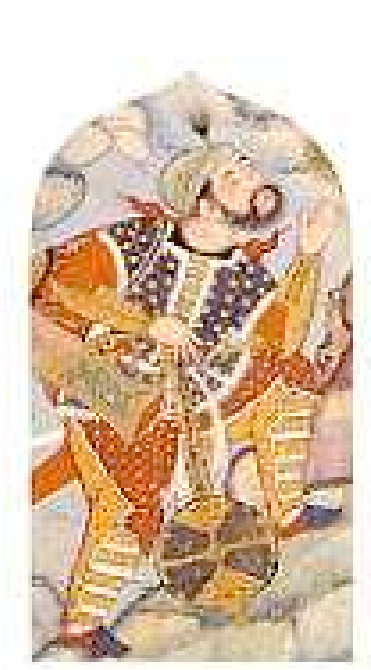
Shammi's paints

The paints he uses are made from natural materials such as stones, gems, dried plants and flowers that are crushed using a pestle and mortar and suspended in a liquid. The preparation of these paints takes a long time. First, the minerals are crushed to form a fine powder and then washed to remove any impurities. This makes an insoluble colour called a pigment. The pigment is then mixed with a thick, liquid binding medium and ground further on a glass slab to break down any lumps. The main binding medium is gum arabic, which comes from acacia trees, but occasionally a little honey or glycerine may also be added to help the paint flow, but also so that the pigment sticks to the cloth or paper support.



Making Indicators and Paints

Mughal artists made their paints from natural materials such as stones and other minerals which have been ground into a fine powder using a pestle and mortar. Natural materials in India are considerably different to those we can find over here. However it is possible to create colours and paints from natural sources found in the home.



Some Examples of a Range of Natural Organic Dyes

1. Madder (Rubia tinctorum L.)
2. Cochineal (dried bodies of the female scale insect Dactylopius coccus)
3. Indigo or Woad (Isatis tinctoria L. and Indigofera tinctoria L. which are dried and fermented)
4. Henna (Lawsonia inermis)
5. Turmeric (Curcuma longa)
6. Saffron (dried stigmas of the Saffron crocus, Crocus sativus)
7. Weld (Reseda luteola)

Some Examples of a Range of Mineral Dyes

1. Cobalt Blue
2. Azurite
3. Prussian Blue
4. Ultramarine
5. Naples Yellow

Activity Two: Making paint

Can you help Shammi to get more coloured paints from natural materials?

Tasks

1. See if you have any materials from the list such as turmeric and saffron. Using your own ideas and with guidance from your teacher see if you can make bright coloured paints from the materials provided.
2. Are there other things from your home that you could use to make paints? (See suggestions below). For example you can use red cabbage which needs to be boiled to release the colours into the water. Discuss you ideas, draw up plans, and **get your teacher to check your plans before you start anything practical.**
3. You may be able to change the colours of each natural paint using a mild acid (such as lemon juice or vinegar) and an alkali (such as bicarbonate of soda or baking powder). In a palate or various oyster shells (be warned the mild acid will attack the shell!) place a small amount of dye and to this add some drops of acid or bicarbonate powder. You may go on to use the paints for a watercolour or to dye a small piece of white cotton.
4. Make a colour chart from the various dyes used and the colours that were made. You must record: **Source of Dye, What We Added, Colours Produced**
5. Mixing paints. Discuss the colours which you have made and what other colours you can create from mixing them in order to make a wider range of colours.

Look for dyes at home, suggestions: try out curry powder, red cabbage, beetroot, different berries such as blackberries, boiling the outer brown skins of an onion, colour from crushing grass and orange peel. Early on in history people dyed clothe by rubbing plants directly onto the material. Let's face it, a stain on your favourite t-shirt is basically the same as a dye!

If you are not sure what a berry in your garden or local park is **DO NOT USE IT** as it could be poisonous.

Safety:

- Eye protection must be worn since some of the sources for dyes and the experimental chemicals could harm your eyes
- Gloves may be a good idea to avoid staining your hands.
- Remember that we are dealing with dyes, so you must not get the materials and colours onto your clothes. They will stain and possibly damage your clothes.
- Dispose of dyes carefully at the end of the lesson – follow your teacher's instructions.

Teachers' Notes

The teacher can decide how much time to devote to this activity, it can be carried it in two double periods with two homework sessions or longer time is not limited.

Curriculum Links

All the activities are linked to the materials topic and for example Changing Materials - Sc3: 2a, 2b. There is also some possible connection with Light – Sc3 : 3e, 3f.

Activity 1 Practical Notes – Dying fabric and testing fastness

The solutions can be made by first heating each dye in boiling water in a pyrex vessel (metal containers affect the dye colour as they react together) and filtering the mixture. The amounts of dye used are 25g henna, 10 strands saffron (colour depends on quality of saffron so double the amount if the colour is not sufficiently visible) and 5 g turmeric in 1 litre distilled water.

Please note though, that you can scale down the quantities, as 1 Litre of water would probably need a 2 Litre beaker. Try _ g in 100 ml of water in a 250ml beaker for example if this is more practical for your circumstances.

Pupils should be encouraged to look at the background of each dye and include this in their research phase for the activity – perhaps as part of their homework. Some information and websites are given below. There are no right answers to how the practical is carried out, only that the conditions used make the tests fair.

Activity 2 Practical Notes – Making paints

There are many other plants, barks and flowers that can be used. Flowers offer interesting dyestuffs, as the majority give shades of yellow or green, even though the flowers themselves may naturally be bright and vivid! See the Additional Supportive Information sections for further suggestions.

Synthetic dyes give bright and vivid colours, many natural dyes do not. A greater range of colours and shades is available from synthetic rather than natural dyes.

In general, flowers and vegetables should be boiled for 15-45 mins. Leaves should be boiled for 30 -120 mins (hard or tough leaves need the longer time, and an overnight soaking prior to boiling) and chopped bark for 1-2 hours (after soaking for 3 days).

More detailed notes and activity sheets can be found on the Chemical Industry Education Centre at the University of York – which has some great online and downloadable resources.
http://www.uyseg.org/colour/activity/act_05/separating_coloured_inks.doc

Teachers' notes relating to this can be found at http://www.uyseg.org/colour/activity/act_05/05_index.htm

Safety Considerations

Eye protection must be worn at all times by students involved in heating experiments and when handling the substances.

Wearing gloves may be a good idea to avoid staining hands.

Dyes and waste materials must be disposed of appropriately – it may be advisable to use a sieve and 'slops bucket' to avoid sinks getting stained or blocked with vegetable matter.

Remind students that they are handling materials to make dyes, so they must not get them onto their clothes. Ensure they wash their hands soon after the experiment.

For further safety guidance refer to the published guides from CLEAPSS www.cleapss.org.uk or ASE www.ase.org.uk

Additional Ideas

Instead of simply dyeing material in activity one pupils can investigate techniques created by artisans in places like Java and West Africa called Tye Dye and Batik. Patterns are created and then the cotton is dyed. One cotton handkerchief for each child is required, already soaked in soda ash, wrung out, and dried. The material is then placed in a bath of dye either fuchsia and sky blue or a commercial fast dye dissolved in water.

How different dyes colour different materials could be used as a continuation to either Activity one or two. Materials such as cotton, acetate, nylon and polyester could be used to compare their different appearances, once they have been treated with the same dye. The dyes will have quite a different effect on different materials.

Further global examples of dyes

Dyeing is a complex process and costs and quality of end product have been improved by the use of synthetic compounds, for examples even in Hennaing hands women save a lot of times in that drying, milling and filtering the fine henna is done mechanically and addition of chemicals ensures the natural henna releases its colour.

In many countries in West Africa, however, local natural dyes not only offer a rich and varied source of dyestuff, but it also offers a sustainable source of income of a handicraft famous all over the world, such as the 'mud' dyed cloth of Mali sold in exclusive shops in London.

References

1. The V&A Colour Trail (British Galleries 1500-1900) www.vam.ac.uk

2. The book 'Mauve' by Simon Garfield tells the story (pub. Faber) ISBN 0-571-20197-0

3. Dyeing and Printing: a handbook ITDG Publishing (see below for website and address)

Internet web site

http://www.chriscooksey.demon.co.uk/
http://www.uyseg.org/colour/activity/act_05/05_index.htm
http://www.itdg.org/html/technical_enquiries/docs/dyeing_textiles.pdf

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Additional Supportive Information for Activity One

BOX A: Henna

Botanical: Lawsonia alba (LANK.), Lawsonia inermis Family: N.O. Lythraceae

Found in Asia, the Middle East and East Africa. The powdered leaves have been in use from the most ancient times in Eastern countries for dyeing the hair, the nails a reddish-yellow and decorating the hands yellow to deep auburn by using a paste made with hot tea, clove oil and spread on the part to be dyed, being allowed to remain for one night. Asian women place henna on their hands and feet to enhance fertility and femininity and avert evil and misfortune, especially in ceremonies such as marriage and childbirth. Since 1890 it has been widely used in Europe for tinting the hair, usually in the form of a shampoo, many shades being obtainable by mixing with the leaves of other plants, such as indigo. For further information, try:
http://www.botanical.com/botanical/mgmh/h/henna-24.html

BOX B: SAFFRON Crocus sativus, a member of the *Iridaceae.*

Saffron, the world's most expensive spice, is derived from the bright red stigmas of the saffron crocus. The origins of saffron are obscure, but the plant is believed to have originated in the eastern Mediterranean, probably Greece, Asia Minor and Persia, and murals showing saffron have been found in the ancient city of Knossos in Crete. Its use soon spread to the Romans, who may have been involved with its introduction into Britain. The Arabs are sometimes credited with the introduction of saffron into Spain around the tenth century. The movement of saffron into India occurred much earlier. There is evidence of its medicinal use in Kashmir in 500 BC.
The medicinal uses of saffron were varied, being traced back to Ancient Roman times. In modern times, however, saffron is used almost exclusively as a culinary seasoning and to colour foods since cheaper synthetic dyes are now available. For further information, try:
http://www.crop.cri.nz/psp/broadshe/SAFFRON.HTM
http://www.magdalin.com/herbal/plants_pages/s/saffron.htm

BOX C: Indigo Indigofera tinctoria, Family: N.O. Leguminosae

First found in India; cultivated in sub-tropical countries. Indigo does not exist ready formed, but is produced during fermentation from another agent existing in the plant called Indocan, and is yellow, amorphous, of a nauseous bitter taste with an acid reaction; readily soluble in water, alcohol and ether.

Indigo was at one time much used in medicine, but now is rarely used. To find out more, visit
http://www.botanical.com/botanical/mgmh/i/indigo05.html

BOX D: Turmeric, Curcuma longa L. Family: N.O. Zingiberaceae

Cultivated in Southern Asia. Cultivated in China, Bengal and Java. perennial plant with the powder actually comes from the dried tubers which are then powdered, or pickled by many Indians. The colouring matter named curcumin; is obtained by digesting turmeric in boiling alcohol, filtering and evaporating the solution to dryness, the residue being digested in ether, filtered and evaporated. For further information, try:
http://www.botanical.com/botanical/mgmh/t/turmer30.html

Additional Supportive Information for Activity Two

- With great thanks to the Chemical Industry Education Centre at the University of York

http://www.uyseg.org/colour/activity/act_05/separating_coloured_inks.doc

Dyestuff	Colour	Collection and preparation	Soaking time	Boiling time	Strain	Simmering time with fabric
Acorns	Brown	As they ripen, and use immediately for deepest colour.	Overnight	1 hour	Yes	1 hour
Avocado	Cream to fawn	2 skins will dye 25g of cloth. Cut the skins into small pieces	Soak overnight 30 mins	Boil for 30 mins	Yes	45 mins
Blackberries	Blue-grey	Fresh ripe fruit, use immediately or freeze till required.	None	15 mins	Yes	1 hour
Coffee	Cream to brown	Used filter coffee grains (or instant coffee)	Overnight (though not essential)	30 mins	Yes	45 mins
Daffodil	Yellow	Fresh heads just as they start to wilt	None	20-30 mins	Yes	45 mins
Dahlia	Yellow or gold	Pick flowers as they show signs of dying	None	20 mins	Yes	45 mins
Elder	Yellow or green	Leaves	None	1 hour	Yes	1 hour
	Pinkish violet	Berries	None	30 mins	Yes	45 mins
Honeysuckle	Yellow	Pick fresh shoots (not woody stems) in mid-May before flowers appear.	None	30 mins	Yes	45 mins
Stinging nettles **HANDLE WITH CARE!** Wear gloves or use tongs /forceps.	Creamy to yellow	Chop nettle plant into small pieces	None	45 mins	Yes	45 mins
Tea	Brown/ orange	Loose tea or teabags	None	30 mins	Yes	1 hour

Additional Information – Substantive or fugitive dyes

Plants or flowers giving a colourfast dye are called **substantive** and those needing a fixative are called **fugitive**. A classroom display of dyestuffs could be divided into these two categories. A separate display can be made of the mineral dye showing the rocks and powdered minerals. Pupils can be allowed to grind one mineral to appreciate the difficulty of doing this.

Substantive dyes, again with thanks to the Chemical Industry Education Centre at the University of York

http://www.uyseg.org/colour/activity/act_05/separating_coloured_inks.doc

coffee (used coffee grains) henna (powder or leaf) avocado (skins) seaweed (bladder-wrack)	blackberries mustard acorns wild mangosteen	onion skins saffron red cabbage beetroot	tea grass ragwort

Fugitive dyes

apple bark betel nut elder (leaves and berries) bracken chamomile flowers	cherry cochineal daffodil flowers dahlia maple bark	oak inner bark turmeric weld woad