TEACHING AND LEARNING NOTES

KEY STAGE 5 RESOURCES [TIME REQUIRED = ONE HOUR+]
Starter activity: Career case study and questions
Foundation activity: Flower power
Higher activity: Buttercup yellow
Extension activity: Visitors
Plenary activity: Busy bees

AIMS

Careers education

Pupils should develop interest in and enthusiasm for science, including developing an interest in further study and careers in sciences.

How science works

Pupils should use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas.

Biodiversity

Pupils will know that:

- adaptations of organisms to their environments can be behavioural or physiological as well as anatomical
- adaptation and selection are major components of evolution and make a significant contribution to the diversity of living organisms.

KEY VOCABULARY

evolution • pollination • spectrum • infra red • ultraviolet • wavelength • interference • diffraction • pigment • structural colour

STARTER ACTIVITY: CAREER CASE STUDY AND QUESTIONS

Ask pupils to read through the career case study in the starter activity worksheet and read the interview either online or have copies printed to provide it in handout form. Students may access the SAPS careers and other materials on PCs in or out of the classroom.

They may then tackle the questions individually and discuss their answers in small groups or open class.

Questions could be set for homework and discussed to set the scene before pupils tackle the practical. Use the discussion to establish why Beverley Glover enjoys being a plant scientist.

A job profile for a research scientist may be found at https://nationalcareersservice.direct.gov.uk/advice/planning/jobprofiles/Pages/researchscientist.aspx

More information can be found in Beverley's Department of Plant Sciences Evolution and Development Laboratory page at http://www.plantsci.cam.ac.uk/research/beverleyglover.html and Women in Biology at Cambridge brief biography at http://www.bio.cam.ac.uk/women/lecturer.html Beverley has also won an award for the best written work on ecology "Understanding Flowers and Flowering" http://plantsci.blogspot.co.uk/2009/09/beverley-glover-wins-book-award.html. The webpage at http://www.plantsci.cam.ac.uk/grads/glover.html outlines some research work in her department

Answers

a) The Department of Plant Sciences at the University of Cambridge.

b) She was fascinated by how plants survived "without being able to run away".

c) She did a degree in Plant and Environmental Biology at St Andrews then a PhD at the John Innes Centre.

d) The interactions between plants and their pollinators.

e) "Finding out things that nobody else knows". She also enjoys it when ideas come together and "you can see a whole research programme opening up" and attending conferences in slightly different fields "to get a broader perspective".

FOUNDATION ACTIVITY: FLOWER POWER

The worksheet activities explore some of the physics of colour and relate it to the mechanisms used by flowers to attract animals.

The visible spectrum demonstrates the normal spectrum as seen by the human eye. Beyond the spectrum shows how infra red and ultraviolet can be detected and introduces the idea that other animals have a different range of 'visible spectrum'.

Pupils can work in pairs or small groups to carry out the activities, though if time is short 'Beyond the visible spectrum' part 1 could be left out or demonstrated. If any group has difficulty obtaining good results, they can be shown the results of other groups.

SAFETY: Pupils should be warned to avoid looking at sunlight directly or through a prism. They should not look at CDs or DVDs in direct sunlight.

Answers

<u>The visible spectrum</u>

b) All the colours may be hard to distinguish. The traditional order of colours is ROYGBIV, though there is a story that Newton was superstitious and invented a seventh colour - indigo. Explanations should include refraction at the air / glass interface, slowing down of wavelengths to different speeds causing dispersion to separate them into visible colours.

c) Visible to the human eye.

<u>Beyond the visible spectrum</u>

a) Infra red wavelengths in sunlight beyond red are detected by thermofilm because they have a heating effect. The light sensitive film is also sensitive to ultraviolet wavelengths in the sunlight. Wavelengths exist that are not detected by the human eye (but they can be detected by suitable receptors.)

b) Bees can detect ultraviolet wavelengths shown to be present in part 2.

c) Although humans cannot see outside the 'visible spectrum', other animals such as bees have different 'visible spectra'. Flowers are likely to reflect 'colours' in these wavelengths.

See 'How nature dresses to impress' at www.colours.phy.cam.ac.uk for more information and pictures of how flowers appear to bees.

<u>Flower colour by adding and subtracting</u>

a) Pigments absorb certain wavelengths and reflect others which give the colour of the flower. Mixing pigments subtracts wavelengths red, green and blue absorb all wavelengths leaving black. Additive colour mixing occurs when light is split at thinly separated surfaces or by narrow grids (on 1/1000 mm scale) which cause waves to add together when peaks coincide (constructive interference) or cancel out when peaks and troughs coincide (destructive interference). Iridescence occurs when the angle of the incident light or of viewing is changed, so the interference patterns seen alter and the colours change. The small structures used for colour are called nanostructures.

b) Possible advantages include: Brighter colours are produced which may be more easily seen or more attractive to visitors; The flower can modify existing structures and not have to put resources into making pigments.

c) Evolution makes plants fitter. Artificial selection by humans develops varieties with characteristics desired by humans, but not necessarily those that aid survival. For example, flower colour can be altered, but only one colour is likely to be most attractive to pollinators. This colour is likely to be seen in the original wild variety.

d) For example, the use of 'photonic nanoparticles' makes iridescent shimmer and deeper, brighter colours possible.

For more information, see a lecture by Peter Vukusic at http://www.iop.org/resources/videos/education/schools-and-colleges-lecture/page_53537.html

Pupils might be encouraged to watch this for homework or out of interest. The end of the video includes a section on butterfly scales made by L'Oreal. Images and an explanation of Morpho butterflies can be found at www.colours.phy.cam.ac.uk/ferns-and-butterflies. Images of structures used by beetles can be found at http://www.imerys-paper.com/pdf/Brilliant_Whiteness_in_Ultrathin_Beetle_Scales.pdf.

HIGHER ACTIVITY: BUTTERCUP YELLOW

Pupils can compare their efforts with actual newspaper articles, for example http://www.dailymail.co.uk/sciencetech/article-2073862/Real-reason-buttercups-glow-yellow–love-butter.html or http://www.telegraph.co.uk/gardening/8953426/The-reason-why-buttercups-glow.html.

EXTENSION ACTIVITY: VISITORS

Pupils are asked to record observations on insects, especially bees, visiting flowers to attempt to determine factors which the insects find attractive. They could do this as a homework activity, or they could work in pairs or small groups and then exchange ideas. The second part of the activity, designing an investigation in outline could be done individually or discussed in class.

The Royal Society Summer Exhibition 2011 included an exhibit by Beverley's team from Cambridge, see 'Colour in nature' at http://royalsociety.org/summer-science/2011/colour-nature/ which includes a useful short video (see first 2.05 minutes) which includes how iridescence is being investigated.

More information on flower structure and attraction can be found at 'Everything you know about daisies is wrong' at http://io9.com/beverley-glover/ and 'Blowing in the wind: how hidden flower features are crucial for bees' at http://www.britishecologicalsociety.org/about_bes/press/press_releases/flower_features_for_bees.php.

PLENARY ACTIVITY: BUSY BEES

Pupils are asked to brainstorm and discuss 'Do bees matter'. Ideas might include that they are essential to all flowers pollinated only by them, that such flowers might include important food crops, especially those that produce seeds or fruits. Bees may not matter if other pollinators can replace them. Perhaps new crops could be bred or engineered that attract other insects? Reference may be made to declining populations and how factors like use of insecticides and climate change might affect their distribution and abundance.

TECHNICIAN NOTES

CAREER CASE STUDY

The video is located at the SAPS website in the Student section on careers: http://www.saps.org.uk/students/careers/811

Copies may be printed for student use or they may be encouraged to register and read it online.

FOUNDATION ACTIVITY: FLOWER POWER

Method A: The visible spectrum

Equipment and materials

- Equilateral glass prism
- A4 white paper or board
- Source of white light (lamp, ray box, sunlight)
- Digital camera (optional)

Summary of method

Pupils form a visible spectrum using a prism fixed into the side of a cardboard box. Boxes should be large enough to place an A4 sheet of paper inside and deep enough to shade the spectrum produced.

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Method B: Beyond the visible spectrum Part 1

Equipment and materials

- Cardboard box (no lid)
- Equilateral glass prism
- Scissors
- Adhesive tape
- White paper
- Strip of thermofilm
- Fine marker pen
- Adhesive tape
- Digital camera (optional)

Note: this investigation requires good sunlight, so it should be planned and prepared ahead and done when the opportunity arises.

Summary of method

Pupils form a visible spectrum using a prism fixed into the side of a cardboard box, but place thermofilm into one side of the spectrum to show the presence of infra red wavelengths.

Method C: Beyond the visible spectrum Part 2

Equipment and materials

Same as *Method B: Beyond the visible spectrum Part 1*, plus

- Light sensitive paper such as sun print paper in an envelope
- Trough of water (for sun print paper) or other means to develop light sensitive paper as required

Summary of method

Pupils form a visible spectrum using a prism fixed into the side of a cardboard box, but this time place light sensitive paper into one side of the spectrum and develop it to show the presence of ultraviolet wavelengths.

Method D: Flower colour by adding or subtracting

Equipment and materials

- Red, green and blue solutions in test tubes (such as food colours or beetroot, chlorophyll and blueberry extracts)
- Test tube rack
- CD or DVD

Summary of method

Pupils mix coloured solutions to obtain black, demonstrating the absorption of wavelengths from whitelight, eventually to give no reflection and black. CDs or DVDs are used to show how diffraction of white light can give bright colours by additive colour mixing.

Safety (all methods)

Risk assessments should be carried out for all activities: see your local safety guidance, e.g. CLEAPPS or SSERC.

Pupils should be warned to avoid viewing sunlight directly or through the prism.

HIGHER ACTIVITY: BUTTERCUP YELLOW

Equipment and materials

The article to be read by students can be printed or they can be asked to access it online if internet connected computers are made available.

CAREER CASE STUDY

Beverley Glover is a lecturer and research scientist at the University of Cambridge. She has a special interest in how flowers attract insects to pollinate them.

Beverley gave an interview about her career and work. You can find this on the SAPS website in the Student section on careers: http://www.saps.org.uk/students/careers/811

(Or you may be given a printed copy.)

Read what she had to say then answer the questions.

QUESTIONS

a) Which department does Beverley work in?

b) Why did she decide to work with plants?

c) How did she get started?

d) What does she research?

e) What does she enjoy about her research work?

You will explore some aspects of the science of pollination in: *Flower power*.

FLOWER POWER

Beverley Glover enjoys discovering all kinds of new things but, as a plant scientist, her main interest is in the evolution and development of features of flowers which attract pollinating animals.

Plants can't move so those that do not self-fertilise need animals or the wind to carry pollen from one plant to another. Flowers have the power to attract visitors. Millions of years of evolution have allowed flowers to develop sophisticated mechanisms to attract pollinators and achieve pollination. Although bees are very important pollinators, many plants are specialised to attract other animals, such as beetles, butterflies, moths, flies, birds and even bats and lemurs.

Flowers usually have sugary nectar to reward visiting animals, but extra protein-rich pollen can provide food as well. They use scents and coloured petals to help animals looking for food to find them. Flowers are seldom green, they need to stand out against leaves. Scents need to be attractive to pollinators not humans, so fly-pollinated flowers often smell rotten.

The colour of flowers is not as simple as you may think. The colour of different flowers is designed to attract specific pollinators. These do not necessarily have similar colour vision to humans. Although most flowers use pigments to reflect colours by absorbing different wavelengths of light, scientists have only just discovered that some use structural colour by making diffraction gratings in their epidermal cells.

In these investigations you will be able to find out more about how flowers use colour. You will explore some aspects of biophysics – understanding how physics is used in living systems.

SAFETY: risk assessments must be carried out before any activity is undertaken.

Do not look at the sun either directly or through any prism or reflected from any shiny surface.

METHOD A: THE VISIBLE SPECTRUM

EQUIPMENT

Equilateral glass prism • A4 white paper or board • Source of white light (lamp, ray box, sunlight) • Digital camera (optional)

PROCEDURE

01) Hold the prism between your light source and the white paper or board. If you use a ray box, you can stand the prism on its side and shine a single ray at the prism. The paper or board will need to be vertical.

02) Rotate the prism until you get a rainbow pattern on the white surface. Increase or decrease the distance between the prism and the white surface to get the best effect. This pattern is called the white light spectrum. If you can, take a photograph with a digital camera.

INTERPRETING YOUR RESULTS

a) Sketch a labelled diagram or print a photograph to show your results. List the colours you can see.

b) Explain what is happening. Refer to refraction, dispersion, speed, wavelength and colour. You may need to do some research.

c) Why is this called the visible spectrum?

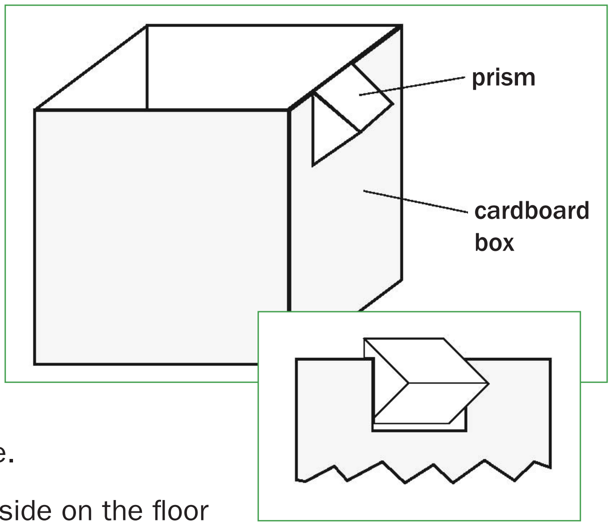
METHOD B: BEYOND THE VISIBLE SPECTRUM PART 1

Note: these investigations require good sunlight, so they should be planned and prepared ahead and done when the opportunity arises.

EQUIPMENT

Cardboard box (no lid) • Equilateral glass prism • Scissors • Adhesive tape • White paper • Strip of thermofilm • Fine marker pen • Sunny day • Adhesive tape • Digital camera (optional)

PROCEDURE



01) Hold one of the square faces of the prism flat against the centre of the top edge of the open box. Draw round it with the marker pen.

02) Cut out just inside the lines made by the marker pen to make a hole to wedge the prism in.

03) Fit the prism in the hole so it is held in place (triangular sides vertical). Trim the hole slightly if the hole is too small. Cut a new hole on another side of the box if it is too large.

04) Use sticky tape to fix a sheet of white paper inside on the floor of the box.

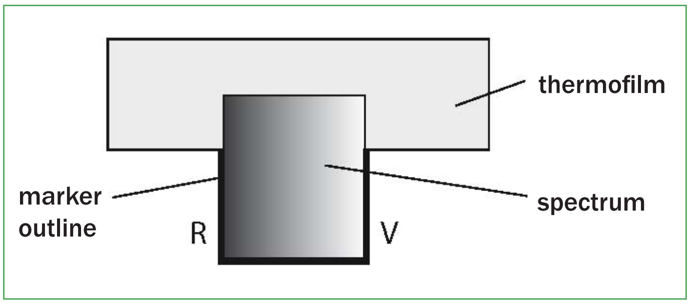
05) Place the box in full sunlight with the prism towards the sun. Safety: do not look at the sun directly or through the prism.

06) Use books (or similar) to raise the sunny side of the box so that the inside is in shadow.

07) Rotate the prism until you get a spectrum on the paper in the base of the box.

08) Tilt the box and move the prism until you get the widest spectrum that you can.

09) Draw around the spectrum with the marker pen. Label one end R for red and the other V for violet. If the box or sun move you should still be able to get the spectrum back in the same place.



10) Tape a piece of thermofilm on the paper so that it extends beyond each end of the spectrum, but leave part of the spectrum to one side so you can see where the red and violet end.

11) Observe and record any changes that take place in the thermofilm. Sketch a labelled diagram (or use a digital photo) to show your results.

INTERPRETING YOUR RESULTS

Explain what happened. You may need to do some research.

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METHOD C: BEYOND THE VISIBLE SPECTRUM PART 2

EQUIPMENT

Light sensitive paper in an envelope • Trough of water (for sun print paper) or other means to develop light sensitive paper as required • ruler (mm) • As for part 1: Cardboard box (no lid) • Equilateral glass prism • Scissors • Adhesive tape • White paper • Fine marker pen • Sunny day • Adhesive tape

PROCEDURE

01) Keep the light sensitive paper in the envelope out of the light until you need it.

02) Set up the box to obtain a spectrum on a piece of white paper as in part 1.

03) Quickly place the light sensitive paper in the shaded bottom of the box so that the spectrum falls on the centre of it. If using sun print paper, place it coloured side up.

04) Draw around the spectrum and label the ends R or V for red and violet.

05) Leave the light sensitive paper until it starts to change colour. Sun print paper will begin to turn pale blue and the part under the spectrum should turn white. This may take 10-20 minutes.

06) Remove the light sensitive paper and quickly place it back into its envelope without exposing it to direct sunlight. Leave it in the envelope until you are ready to develop it.

07) Develop the paper. For sun print paper:

- **a)** Rinse well in a trough of water. Blue colour should wash away from areas exposed to less sunlight energy.
- **b)** Hang up the paper to dry. The water fixes the paper so it will no longer react to light.

08) Measure (to nearest mm) and record the width of the visible spectrum and the width of the dark area on the light sensitive paper. Sketch a labelled diagram (or use a digital photo) to show your results, including measurements and any observations of changes in the light sensitive paper related to the visible spectrum.

INTERPRETING YOUR RESULTS

a) Explain what has happened. You may need to do some research.

The wavelengths that are visible to any animal depend on the photoreceptors (light sensitive cells) it has. Different animals have different visual systems. You are probably able to see a visible spectrum using eyes which are most sensitive to red, green and blue wavelengths. Bees have photoreceptors that are most sensitive to green, blue and ultraviolet. Many birds can see from red to ultraviolet.

b) Which investigation revealed the part of the spectrum that bees are able to see?

c) How might flowers be different to what you can see?

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METHOD D: FLOWER COLOUR BY ADDING OR SUBTRACTING

EQUIPMENT

Red, green and blue solutions in test tubes • Test tube rack • CD or DVD

PROCEDURE

01) In one of the test tubes, mix the red, green and blue coloured solutions with each other.

02) Record your observations.

03) Hold a CD or DVD with the shiny recording/playing surface towards you. Move it around with a light source such as a window behind you. Try to get as much colour as you can.
Safety: Keep out of direct sunlight.

04) Record your observations.

INTERPRETING YOUR RESULTS

Structural colours are well known in animals like butterflies, beetles and birds (such as in peacock feathers). Beverley has worked with physicists like Dr Peter Vukusic at Exeter University. He has investigated how butterflies and beetles can produce bright iridescent colours. For example, he used an electron microscope to reveal the detailed structure of the scales on butterfly wings and explained colour production such as the bright blues of the Morpho butterfly.

Plant scientists now know that flowers also use structural colours. Beverley's team at Cambridge have discovered that quite a few flowers (including certain iridescent tulips like 'Queen of the night') make diffraction gratings (like a CD or DVD). They use very fine lines of cuticle on their epidermal cells.

Use your observations to consider the difference between colours obtained using pigments (molecules) and colours obtained using structures. You will need to do some research.

a) With reference to your observations above, explain:
- **i)** how flowers can create different colours by mixing them in a subtractive way
- **ii)** how colours can be obtained without pigments - how flowers can use additive colour mixing (include the role of constructive and destructive interference and how iridescence occurs.

b) Suggest some possible advantages to flowers of using structural colour rather than pigmentary colour.

c) Why might domesticated plant varieties be less successful at achieving pollination than their wild relatives?

d) Suggest why the cosmetics firm L'Oreal asked Peter Vukusic to help them to develop new lipsticks and nail polishes based on his findings on structural colours. If you have access to the internet, read "Butterfly wings on every eyelid" at:
http://www.wired.com/medtech/health/news/2005/09/68683

BUTTERCUP YELLOW

Beverley's team have worked with scientists in the University of Cambridge Department of Physics to discover why buttercups reflect yellow on chins.

a) Read the Cambridge University Research News article "Why buttercups reflect yellow on chins" at http://www.cam.ac.uk/research/news/scientists-discover-why-buttercups-reflect-yellow-on-chins-%E2%80%93-and-it-doesn%E2%80%99t-have-anything-to-do-with-whether-you-like-butter/.

b) Write a short newspaper article to explain the findings of the plant scientists to the 'interested layperson' - people who have only a basic understanding of science but would like to know about the science of buttercup colour behind the children's game 'do you like butter?'.

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VISITORS

Successful pollination is vital to the survival of many plant species and also to maintain yields in many crops. Beverly and her team are discovering new things about the mechanisms which plants use to attract animals and to maximize pollination.

What are the features which attract animals to flowers?

Can you make any discoveries yourself?

Carry out an observation of the behaviour of animals visiting flowers.

Start by concentrating on bees.

You will need a warm, sunny day and a place with a variety of flowers where insects are plentiful and active. Note: you are just going to take a 'snapshot' to get ideas that you might test in a full scale investigation.

Make notes to record which flowers the bees are visiting. If possible identify the plants, if not record their main features and give each type a letter A, B, C, etc.

Note the date and time of day and the prevailing weather conditions.

Observe for a while and then draw up a table to record any features that you think might be significant, for example:

- flower size: average and range
- number of flowers per plant / in area
- flower colour(s)
- scented?
- nectar?
- position and size of anthers?
- type of pollen (e.g. size, sticky or spiked?)
- time spent at each flower
- time flying in area
- type of flight path
- behaviour in flower

You may wish to record other factors, for example you may want to distinguish bee species or at least bee types, or keep a record of other visiting animals.

You may need to do further research, including dissection to reveal flower structures and microscopy to investigate pollen.

Make a suggestion for a scientific investigation.

a) State a hypothesis that could be investigated.

b) Identify dependent and independent variables and indicate what you would record or measure.

c) List factors that would need to be kept constant or controlled.

d) Suggest any problems that you might encounter if you carried out your investigation.

BUSY BEES

- Brainstorm the question: **"Do bees matter?"**
  Think of as many reasons as you can why they do and why they don't.
- List the ideas in order of importance.
- Hold a class discussion – do you all agree?