# Exploring Science Extra

## How Science Works

# Spring Flowers

6

ALWAYS LEARNING

PEARSON

# 6 Exploring Science Extra

## Introduction

The Earth receives all its light energy from the Sun. The spinning of the Earth on its axis every 24 hours creates night and day. The orbit of the Earth around the Sun also affects the amount of light that some parts of the Earth's surface receive at different times of the year. This is because the Earth's axis is tilted.

Welcome to the latest Exploring Science Extra pack. As ever, the pack contains a Student Booklet, a Teacher's Guide (containing suggested activities) and Activity Sheets (to support some of the activities).

With the springing of spring, this pack takes a topical look at spring flowers. In so doing, we hope that the pack will inspire students to take more interest in the natural cycles that happen around them every year.

The pack contains the usual mixture of activities; some of which are fun extensions to existing KS3 work and some of which take students a little beyond KS3. However, all the activities will enable students to practice key scientific skills. There is a focus on data analysis in this pack, allowing students to appreciate the different ways in which data is collected and analysed. We are particularly grateful to Anne Phillips, who has made her phenological data of snowdrop flowering available.

Phenology is the study of the timing of natural cycles, particularly in relation to climate. The Woodland Trust has set up a survey site called Nature's Calendar and are encouraging everyone to get involved with recording the timing of phenomena such as flowering, leaf opening, migrating bird arrivals etc. This is a real scientific project in which it is easy to take part. For more information have a look at:

http://www.naturescalendar.org.uk

## Did you know?

A new draft Key Stage 3 National Curriculum is available, which you can download from here:

http://www.education.gov.uk/schools/teachingandlearning/curriculum/nationalcurriculum2014/b00220600/consultation-national-curriculum-pos

I personally have some misgivings about it, including the absence of any mention of the germ theory of disease in Key Stages 1, 2 or 3. Whatever your thoughts on the draft National Curriculum, you have until the 16th of April to let the DfE know your views.

The Exploring Science Team would also love to hear what you think of the draft. How will it affect you? How would you like to see Exploring Science evolve?

With best wishes for Easter,

**Mark**

Mark Levesley,

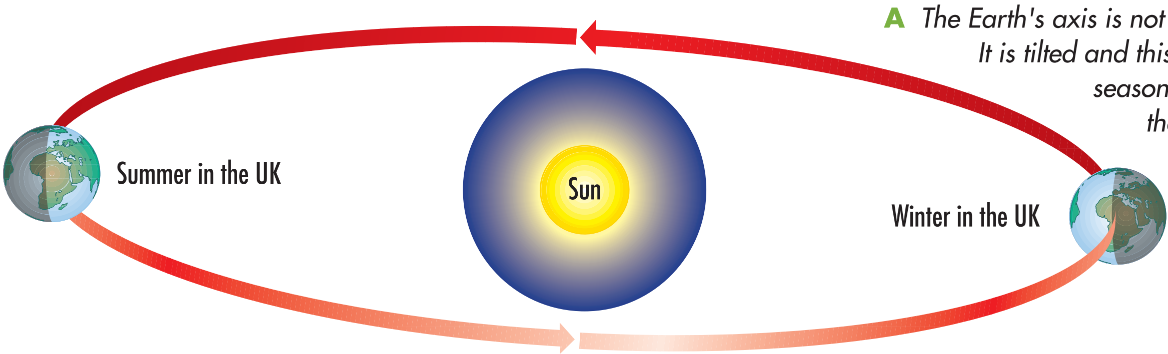
Series Editor

We're very grateful to Tim Sparks from University of Cambridge for helping us source the phenological data and to Anne Phillips for allowing us to use it. We are also very appreciative of all the help provided by Dr Beverley Glover and Dr Alex Murphy from the Department of Plant Sciences at the University of Cambridge, and also to Dr Silvia Vignolini from the Department of Physics at the University of Cambridge. The daylight and UV photos of the flowers on page 3 were kindly provided by S. Vignolini, University of Cambridge, Department of Physics, Cavendish Laboratory and M. M. Thomas, University of Cambridge, Department of Plant Sciences. The bluebell wood and wildflower photos of page 2 were kindly supplied by Sue Kearsey. All other photographs courtesy of Veer Image Library www.veer.com.

# 1 The effects of the Sun

## Light and seasons

The Earth receives all its light energy from the Sun. The spinning of the Earth on its axis every 24 hours creates night and day. The orbit of the Earth around the Sun also affects the amount of light that some parts of the Earth's surface receive at different times of the year. This is because the Earth's axis is tilted.




**A** *The Earth's axis is not vertical. It is tilted and this causes seasons nearer the poles.*

Around the Equator, the surface receives 12 hours of light and 12 hours of dark every day. Nearer the poles, when the axis is tilted towards the Sun, the surface receives more hours of light than of dark in every 24 hours. The opposite is true when the axis is tilted away from the Sun. This creates the seasons of summer and winter – seasons that are more obvious the nearer you get to the poles.

**B** *Midnight in an Arctic summer – the Sun remains above the horizon all night. In the winter, the Sun may not rise above the horizon for several weeks.*

## Warmth

The Earth also receives heat energy from the Sun. So the amount of heat energy received is greater in summer than in winter for a particular area on the Earth's surface. These changes in heat energy and light energy affect the environment and all the organisms that live in those areas.

**C** *One of the more dramatic effects of winter temperatures is on the changing state of water to ice.*

**Key points in the seasons are:**

- equinoxes (means *equal nights*) – day and night are 12 hours long, about 20 March and 22 September
- solstices (means *sun stands still*) – when day length changes from getting shorter to getting longer or vice versa, about 21 June and 21 December.

# 2 A woodland in spring

It is easy to see the effect of seasons on a British woodland.

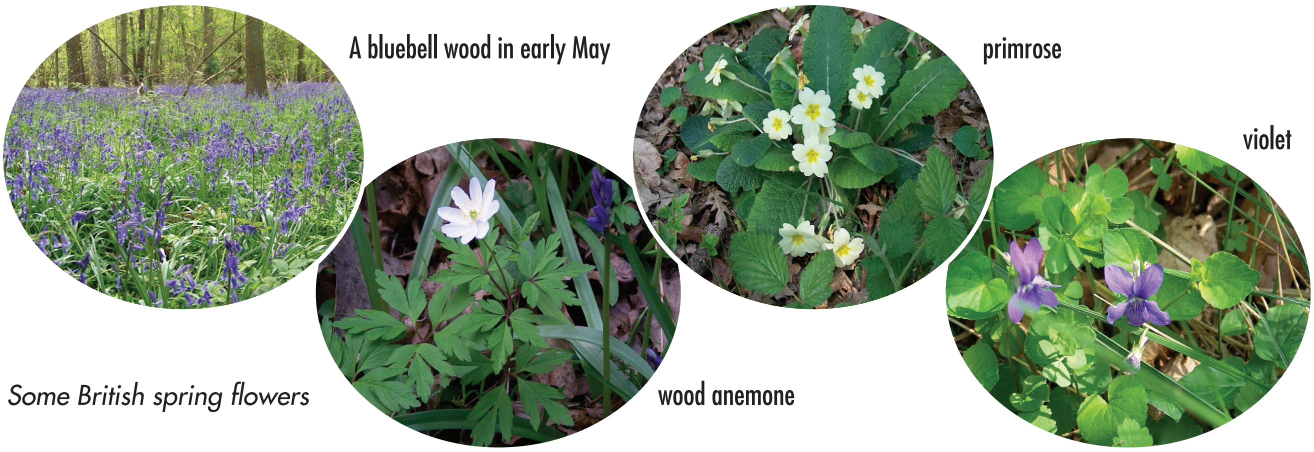
During spring, broad-leaved trees produce new leaves.

During summer, the tree leaves create a dense shade on the woodland floor.

In autumn, the broad-leaved trees drop their leaves – we say they are deciduous.

**D** *A woodland path in different seasons.*

## Woodland flowers




**E** *Some British spring flowers*

Although the woodland floor is covered in these flowering plants in spring, by the time that the tree leaves are fully developed there may be no sign of them at all. They will have come into leaf, flowered, reproduced and then died back completely. This is because too little light reaches the woodland floor during the summer for photosynthesis.

As they photosynthesise during the spring, the woodland floor plants store extra food in storage organs (such as bulbs). For the rest of the year, the storage organs remain dormant (not active) underground, waiting for the next spring.

*The storage organs are also important as a form of asexual reproduction because, when they are large enough, they bud off new bulbs. This helps the plant make more new plants, which is particularly important if insects fail to pollinate the flowers because it is too cold for the insects to fly.*

# 3 About flowers

**F** *An early spring bee collects pollen from a goat willow catkin. The pollen is mixed with nectar collected from plants and packed into cells in the hive. This 'bee bread' is the food for developing young bees.*

## Flower colours

Flowers contain the male and female reproductive parts of plants. As in animals, the male and female sex cells (gametes) must come together for fertilisation. However, unlike animals, plants don't move from place to place. So plants depend on other ways of getting the male sex cells to the female reproductive parts.

Many plants depend on insects to carry their pollen from one flower to another. The pollen contains the male gametes.

The insects are tempted to the flowers with a 'reward' usually in the form of food from the pollen or a sweet syrup, called nectar, made in nectaries near the base of the flowers.

As the insects travel from flower to flower, gathering the food, they also carry pollen on their bodies. When pollen reaches the female part of a flower of the right species, this is known as pollination. The male gametes in the pollen can then fertilise the female gametes in the flower and the plant will produce seed.

Different colours of flowers may attract different kinds of insects.

- Bees are mostly attracted to flowers that are yellow, mauve (pink-purple)or white.
- Day-flying butterflies prefer flowers that are red, yellow, blue or purple.
- Night-flying butterflies and moths like pale colours such as white, pale yellow or light purple.
- Flies and beetles love bright yellows, purples and white.

**G** *A spring-flying brimstone butterfly feeds on a coltsfoot flower.*

Many insects can see ultraviolet light, and many flowers have additional markings that are only visible to us when ultraviolet light is shone on them. These markings are often stronger nearer the centre of the flower where the nectaries are. So the markings are often known as nectar guides.

**H** *An Arctotisflower looks mostly white in light that is visible to humans (left photo). To insects that can see UV light (right photo), the dark 'nectar guides' are obvious.*

# 4 About flowers continued

I Has this snowdrop flower opened a little too early?

## The timing of flowering

Spring-flowering plants need to get the timing right when they flower. The flowers need to open when it is warm enough for flying insects that pollinate the flowers, but not so late in the spring that the woodland trees are fully covered in leaves.

Many spring-flowering plants respond both to temperature and to light intensity to get the time of flowering right. They first need a period of cold to stimulate flower buds to form. This cold treatment is called vernalisation, and prevents flowers opening until after winter.

Photoperiodism is how the plant identifies and responds to changes in day length. Spring-flowering plants will often only flower when the number of daylight hours is greater than a particular amount. This guarantees that the plant doesn't flower in an unusually warm spell in the winter.

## Keeping cut flowers fresh

Many cut flowers bought in shops come with a sachet of 'plant food'. This isn't really food, but a solution that helps the flowers stay fresh longer.

Home remedies to keep cut flowers fresh include placing a coin that contains copper at the bottom of the water, a crushed aspirin, or a squeeze of lemon juice or splash of vinegar added to the water.

All these treatments reduce the rate of growth of microorganisms, such as bacteria and fungi, which are found on the plant's surface. Copper is particularly poisonous to fungi, and aspirin, lemon juice and vinegar are all acidic.

Keeping the flowers cool also helps, as does making sure the stems are not out of water for long. This makes sure the flowers have all the water they need to stay fresh.

Even so, different flowers last longer than others. Irises may only last a few days, daffodils may last a week, while chrysanthemums may last 2 or 3 weeks.

J A bunch of spring flowers is a quick way to brighten up a room in spring. However, if they are not looked after well, they will quickly fade and drop their petals.

*Remember that it is illegal to take flowers from the wild. This is because it damages the chances of the plants reproducing and can lead to them dying out. Your spring flower bouquet should only come from a shop or from a garden with the owner's permission.*

# 5 Plants in the past

**K** *Ferns and mosses often grow in places where there the soil is not deep enough for the roots of flowering plants.*

Most of the plants you see belong to one major plant group, the flowering plants. This group includes all plants with true flowers, from the small ground-hugging daisy to the Australian mountain ash tree that can grow over 100 m tall. The group includes plants with broad leaves, as well as the narrow-leaved grasses.

There are some other major plant groups:

- conifers, which protect their seeds in cones and are found mainly in colder parts of the world usually as trees
- ferns, a few in tropical places grow to tree size, but are usually much smaller
- mosses and liverworts, which usually grow close to the ground in damp places.

Ferns, mosses and liverworts don't produce seeds. Instead they form spores, which can be carried away to new places where they grow into new plants.

## Plant fossils

Plant fossils give us evidence of plants that grew many thousands or millions of years ago. Plant fossils can only form if plant tissues are buried in sediment soon after the plant dies, and before decay starts to break down the tissues.

Plant fossils can form in different ways.

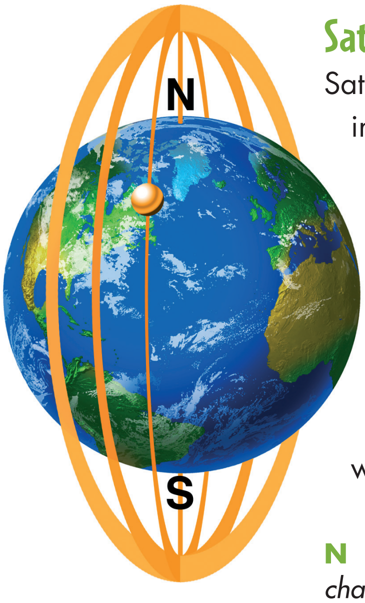
- The plant tissue can be replaced with minerals to make rock that looks like the original tissue.
- The carbon compounds in the leaf can be changed to a coal-like material, forming a flattened black layer between the layers of rock.
- Casts and moulds are formed when the plant tissue decays but the space in the sediments that is left is replaced with rock. A cast is formed by the rock that replaced the plant tissue. A mould is the rock that forms around the cast.

The type of fossil formed depends on the conditions inside the rock while it is forming.

**L** *This fossil fern leaf is about 300 million years old. The plant grew in swampy land in the UK when the climate was warmer and wetter than today. There were no flowering plants at this time.*

**M** *This fossil laurel leaf is about 50 million years old. It is very like a leaf from a living laurel (a flowering plant), showing that conditions in southern England were similar then to what they are now.*

# 6 Predicting the future




## Satellite data

Satellites that orbit the Earth are used to gather all kinds of data. Some data is interpreted as temperatures at the Earth's surface and at different heights through the atmosphere.

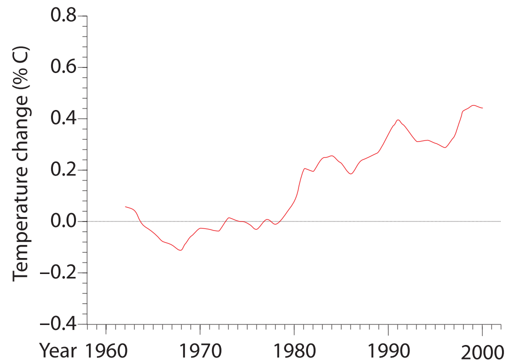
Plotting the temperature estimates over time can give information about how the Earth's temperature is changing. However, different scientists interpret the satellite data using different calculations and so may produce different estimates.

Most estimates of surface temperature do suggest that the Earth has been getting warmer since around 1970.

**N** *This satellite is in a polar orbit (goes around the poles – orange lines). By slightly changing the orbit each time, the satellite can take measurements of the whole Earth.*

## Phenology

Phenology is the study of naturally occurring activities that are affected by seasons and climate. For example, spring flowers usually open at about the same time each year. However, the exact date on which they open will vary from year to year, affected by conditions in the environment.




**O** *One interpretation of the satellite data as temperature at the Earth's surface over the past 150 years. (The values are relative to the mean temperature in 1900.)*

By recording the date of first opening of a particular species of flower over many years, scientists are able to judge whether there are any long-term trends in environmental conditions. These data show a similar trend to the satellite data.

Phenology can be used to predict the effect of increasing temperature on organisms. This includes the way different organisms interact.

**Example**

*Orange-tip butterflies lay their eggs on garlic mustard flowers. The timing is critical – the caterpillars must emerge as the seeds form in the flower, so that they have food to eat. Phenology studies have shown that garlic mustard flowering is on average getting earlier due to climate change. Studies of the butterfly show that they are also laying their eggs earlier, in time with the flowering. So the caterpillars will continue to have food, and the flowers will continue to be pollinated.*

**P** *Orange-tip butterfly feeding on garlic mustard flower.*

# 6 Spring flowers

## Spring adaptations

*Exploring Science* link: 7C

This activity links to the topic of adaptations for survival in particular conditions. Show students some of the pictures of spring-flowering plants in the Student Booklet or other sources, and ask them to work in pairs or small groups to consider what adaptations the plants would need to do well in their environment. Point out that many of our most well-known spring plants, such as snowdrops and bluebells, live in shady woodland. Ask students what problems this might cause for ground-cover plants in terms of growth as the spring progresses into summer. Take examples from around the class for discussion. If needed, stimulate the discussion with prompts about how light and temperature will change from winter to summer.

Ask students to gather information from the Student Booklet, from other books and/or the internet to answer the question 'How are spring-flowering plants adapted to living in a seasonal climate?' They could construct a poster or write a short illustrated report to display their findings.

## Flower petal indicators

*Exploring Science* link: 7E

This is a practical investigation using pigments extracted from flower petals. Activity Sheet 1 describes a method in which the pigments are extracted using alcohol. Alternatively the pigments could be extracted by boiling in distilled water, although this doesn't work so well for some species.

A range of coloured spring flowers could be used to follow the theme of this pack, but these should not be collected from the wild. If available (on school grounds or from gardens with permission of the owner) remember only to take a small number of scattered flowers so that each plant still has a several flowers for pollination. A greater range of colours may be possible using cut flowers from a florist. Flowers that are already starting to fade may be cheaper but still useful for the investigation. Suitable flowers include pelargonium (red in acid, blue in alkali) and petunia (pink in acid, violet in alkali), but it won't matter if some species (e.g. buttercup – yellow in all pHs) don't change colour.

**Safety note:** Students should wear eye protection. Refer to CLEAPSS Guide G42 *Plants for Classrooms* for a list of suitable and non-suitable plants for this practical.

For some students, it may be appropriate to discuss the answers to Question 2 on Activity Sheet 1 as a group or class, to help them link each answer to a suitable explanation.

**Resources (per group/student):** test tubes (one per flower species) + rack, marker pen, mortar and pestle, flowers of different colours from different plant species (e.g. buttercup, pelargonium, tulip, iris), 70% alcohol (FLAMMABLE) (IDA), pipettes, Universal indicator in dropping bottle, pH scale, spotting tile, test solutions of a range of pHs labelled with name of solution but not its pH (e.g. 1 mol $dm^{-3}$ hydrochloric acid (pH 1), 1 mol $dm^{-3}$ ethanoic acid (pH 3), 1 mol $dm^{-3}$ sodium bicarbonate solution (pH 8); 0.5 mol $dm^{-3}$ sodium hydroxide solution (pH 10), distilled water (approx. pH 7)), beaker of clean tap water + access to tap water, eye protection. Activity Sheet 1.

## Modelling the seasons

*Exploring Science* link: 7L

Ask students to work in small groups to develop a physical model of the way in which the Earth rotates on its axis during one day, and around the Sun during one year. They could do this by building a model using simple junk materials, as described on the Exploratorium web page http://www.exploratorium.edu/ancientobs/chaco/HTML/TG-seasons.html/, or they could use a globe, torch and themselves to act out the movement, such as on the website http://www.teachersdomain.org/resource/ess05.sci.ess.earthsys.lp_seasons/.

Some students may need support in working out how to model the tilt of the Earth's axis at a suitable angle.

When students have developed their models, they should be given the opportunity to demonstrate how their model explains why there are no seasons along the Equator while seasons become more extreme as you get nearer to the poles. They should also explain why, when it is winter in the higher latitudes of one hemisphere, it is summer in the higher latitudes of the other hemisphere.

**Resources (per group)**: Please see suggested websites for details.

# 6 Spring flowers

## Keeping cut flowers fresh

***Exploring Science* link: 8C**

This activity gives students the opportunity to plan a practical investigation focused on identifying control variables. If available, start the activity with a bunch of cut spring flowers, such as daffodils, and tell students that you want to find a way of keeping them fresh for as long as possible.

First, ask students to read the section in the Student Booklet about keeping cut flowers fresh. Then as a class discussion, ask students to suggest ideas from the Booklet or from their own experience on how to keep a vase of cut flowers fresh. Link the discussion with work on the factors that affect microbial growth so that students can suggest reasons why the various ideas might extend freshness (generally by reducing the rate of microbial growth, which damages the plant tissue and reduces water uptake by the stems).

Then ask students to work individually, in pairs or small groups, to consider all the variables that might need to be controlled when carrying out an investigation to find the best method for keeping the flowers fresh for longest. For some students, you may need to hint about how the flowers are prepared (e.g. when and how they are cut, how long they remain out of water) as well as the factors that may vary during the investigation (e.g. temperature, light availability). Students should try to give reasons for controlling each particular variable. If there is time, students could develop this into a full plan for the investigation.

## Leaf fossils

***Exploring Science* link: 8H**

You could begin this activity with a suitable video that shows what leaf fossils look like and possibly also what they can tell us about the environment in which the plants once lived. Suitable videos include http://www.youtube.com/watch?v=dYkybZ9Ncdk and http://www.nhm.ac.uk/nature-online/earth/fossils/glossopteris/index.html.

To help students understand one of the ways that leaf fossils can be formed, and the effect of sediment type on the quality of preservation, ask them to carry out the practical described in Activity Sheet 2. If there is insufficient time or materials, divide the class in half and give one half the fine 'fossil dough' and the other half the coarse 'fossil dough'. The 'fossils' will need up to 24 hours to harden, before the leaves can be removed and the 'fossils' studied. (The details for this method come from http://www.michigan.gov/documents/deq/p06create_304664_7.pdf.)

If there is time, students could use Plaster of Paris to create casts from their moulds. They should then compare how they made their 'fossils' with the way that real fossils form, including the time scales over which fossils form.

**Resources:**

- Fine fossil dough: Mix 125 g cornflour, 250 g sodium bicarbonate and about 250 $cm^3$ cold water in a pan over medium heat for a few minutes until the mixture thickens to a thick paste. Leave to cool, covered with a damp cloth. Knead the mixture and shape into 2 cm-wide balls (makes 25-30). Store in an airtight container or plastic bag in a fridge until needed.
- Coarse fossil dough: Mix 250 g white flour, 125 g salt, 15 $cm^3$ vegetable oil and 5 $cm^3$ alum. Add a small amount of cold water at a time and mix until it has the consistency of bread dough (uses between 125 and 250 $cm^3$ water). Knead until smooth and shape into 2-cm balls (makes 25–30). Store in an airtight container or plastic bag in a fridge until needed. Wear eye protection.

**(per student/group)**: balls of fine dough, balls of coarse dough, selection of leaves with strong features e.g. toothed edges or pronounced veins, Activity Sheet 2.

**Safety**: Refer to CLEAPSS Guide G42 *Plants for Classrooms* for a list of suitable and non-suitable plants for this practical.

# 6 Spring flowers

## UV photography

*Exploring Science* **link: 8K**

This activity looks at how different flowers look in UV and visible light. Use the photographs in the Student Booklet of a flower in daylight and in ultraviolet light to introduce this activity, pointing out that many insects, including bees, can see UV light. Humans are not able to see UV light but, with a UV light source, it is possible to visualise the flower patterns that insects see.

Strong UV sources can be dangerous but the use of reasonably cheap blue light transilluminators (such as the 969 - Long Wave UV Mini-Light from http://www.edvotek.co.uk) will allow reasonable results to be obtained. Flowers should be illuminated with the light in a dark room or box. If you are using a box, lining it with black velvet will allow clearer viewing of the flower.

This could be done as a demonstration, with students then drawing or describing the differences between the flowers in UV and visible light. Or students could try photographing the flowers under the different lights, although this will be dependent on the camera (since most cameras have UV filters fitted). A comprehensive list of suitable flowers, along with descriptions of their colours and patterns in UV and visible lights can be found at http://www.naturfotograf.com/index2.html.

**Resources (for demonstration or per group):** blue light transilluminator, selection of flowers. Optional: digital camera.

## Seasonal photosynthesis

*Exploring Science* **link: 9C**

Activity Sheet 3 supports a data analysis activity that develops graphing skills and the comparison of graphs to draw conclusions and answer questions. The context for the activity is the effect of varying light intensity on photosynthesis.

Some students may need support in deciding how to draw the graph for Question 1, and in answering the questions. Questions 4 and 5 can be simplified by asking why the graphs have a similar shape, and what difference there is in the *y*-axis scale between the two sets of data. From this you could ask which graph represents the plant in a summer month and which graph shows the plant in a cooler month. Students should give a reason for their answers.

The extension Question 7 is an additional challenge for able students.

**Resources (per student):** Activity Sheet 3.

**Answers:**

**1** Line graph like the one on the Activity Sheet using the data from the table.

**2** The line increases from zero in the early morning to a peak of 30 at midday, then returns to 0 in the evening.

**3** Light intensity varies during the day, increasing in the morning till about midday and then decreasing again till evening when it becomes dark. The rate of photosynthesis follows the change in light intensity.

**4** Similarity: same curve shape, peaking at midday. Difference: the peak value is much lower, at 12 rather than at 30.

**5** (a) Light intensity changes in the same way each day, starting in dark, increasing in light till about midday and then decreasing again till evening when it is dark.
(b) The peak rate of photosynthesis is much lower in the graph on the sheet probably because it is a different time of year when light intensity at midday is less.

**6** Nearer to a pole where the light intensity is lower at midday during the winter than in the summer.

(a) The plants get more light, so make more food and can therefore carry out all life processes (including growth) much faster.
(b) If plants kept their leaves all winter, the cells in the leaves would need to respire which would use up glucose/food. If photosynthesis isn't happening fast enough, because of the lower light intensity, then the plant might run out of food for respiration and so die. Shedding leaves reduces the amount of plant cells that need to be supported by respiration over the winter.

# 6 Spring flowers

## Woodland plant life cycles

*Exploring Science* link: 9A, 9D

The Student Booklet contains information on the adaptations of ground-cover woodland plants to the conditions in which they live. These conditions include the changes in light and temperature over the seasons, as well as the increasing shade in early summer caused by the developing tree canopy.

Ask students to read this information and use it to draw a life cycle for a plant such as bluebell. They should include not only the stages within sexual reproduction, of pollination and fertilisation, but also the role of asexual reproduction (through the division of bulbs) as methods of producing new plants.

## Is spring getting earlier?

*Exploring Science* link: 9G

This activity gives students the opportunity to graph a long-term dataset, carry out some mathematical analyses on the data, and interpret the results to draw a conclusion about climate change between 1976 and 2012.

Some students may need support on using the spreadsheet program to calculate means, and using the graphing tools. Question 9 asks students to add a trendline. There is no need for students to fully understand how the line is calculated, but they need to realise that this method is commonly used by scientists for interpreting this kind of data. Students who are able in maths may wish to find out more about regression analysis. You could also ask them to use the trendline on their graphs to calculate the average rate of change shown by the line, by finding the gradient. It can also be useful to point out that it is easy to calculate a trendline on a graph, but this can lead to spurious conclusions if the original data was too limited or unreliable.

In Question 12 you could introduce the term *correlation* to describe two datasets that show a similar pattern. Question 13 effectively asks if any correlation is actually *causation*. It should be easy for students to understand that earlier warm temperatures may drive earlier first flowering, but not flowering driving temperature.

Worksheet 4 supports this activity, and the dataset is presented in Spreadsheet 1.

Resources (per student or pair of students): Worksheet 4, access to computer and spreadsheet program loaded with Spreadsheet 1.

**Answers:**

**2** The graph shows wide variation in temperature, with the lowest value in 1979 and highest in 2008. The years between 1990 and 2010 may show a gradual rise.
**3** Mean temperatures: 1976–80 = 2.8 °C, 1992–96 = 4.8 °C, 2008–12 = 4.04 °C.
**4** The middle mean temperature is the highest, and the first mean temperature is the lowest.
**5** The three means don't seem to show the same pattern as is seen in the graph, so this could be too simple a method to be reliable.
**7** The running mean graph is much smoother than the graph from the raw data. This shows a general rise in temperature more clearly.
**8** This does seem to be a better way to show a trend in the data than just by looking at the raw data.
**10** The trendline shows a gradual increase in January temperature from about 3.4 °C in 1976 to about 5.0 °C in 2012 (an average of +0.44 °C in 10 years). This is similar to the gradual increase identified by looking at the raw data and running means graphs.
**11** A trendline on the first flower data shows that the first flower date is getting earlier, from about day 37 in 1976 to day 20 in 2012 (an average of about –4.7 days in 10 years).
**12** The trendlines show that as average January temperature gets warmer, date of first flowering gets earlier.
**13** The correlation/similarity between the trendlines does suggest that using first flowering dates is a good way of identifying the gradual change in climate.

## Monitoring temperature

***Exploring Science* link: 9J**

Worksheet 5 provides a brief description of some of the ways in which the temperature of the Earth's surface and atmosphere are calculated. If there is time, students could carry out further research on how the data are interpreted in climate modelling, such as on the web pages http://www.metoffice.gov.uk/climate-change/guide/science/modelling and http://www.metoffice.gov.uk/climate-change/guide/science/monitoring

This information could be used in several ways, such as:

- to interpret and draw conclusions from a graph that shows several temperature datasets, e.g. http://en.wikipedia.org/wiki/File:Radiosonde_Satellite_Surface_Temperature.svg
  To do this, ask students to read Worksheet 5, then answer the following questions while looking at the graph:
  – How are the different data sets similar, and how are they different?
  – Give as many reasons as you can for the differences.
  – Suggest reasons for the similarities.
  – In terms of a long-term trend in temperature, what conclusion can be drawn from the graph?
  – Do all the data sets support this conclusion? Explain your answer.
  – Using the evidence of the different data sets, consider how reliable your conclusion is.
- to identify potential weaknesses in the reliability of long-term temperature data sets as a result of the methods used to produce them – this could be presented as a short report, poster or presentation. In this case, encourage students to develop their note-taking skills while they are carrying out their research. Skills Sheet 59 may help with this.

**Resources (per student):** Worksheet 5, Skills Sheet 59

# 1 Flower petal indicators

Some of the coloured pigments in plants, such as in the flower petals, are chemicals that change colour at different pH. So, indicators can be made from some of them. In this investigation, you will extract the pigments from the petals of several plants to test their usefulness as pH indicators.

## Safety

Wear eye protection.

## Apparatus

- test tubes + rack
- mortar and pestle
- ethanol (FLAMMABLE)
- Universal indicator in dropping bottle
- spotting tile
- beaker of clean tap water + access to tap water
- marker pen
- flowers of different plant species
- pipettes
- Universal indicator pH colour chart
- test solutions
- eye protection

## Recording your results

**1** Draw a table to display your results clearly.

## Method

If needed at any time, replace the water in the beaker with clean tap water so that the pipette is thoroughly rinsed each time.

**A** Using a clean pipette, place a few drops of one test solution in a well on the spotting tile. Rinse the pipette thoroughly in clean water. Record the name of the solution and its position on the tile.

**B** Repeat step A for each test solution, making sure you rinse the pipette thoroughly each time.

**C** Add one or two drops of Universal indicator to each well on the tile that contains a test solution. Use the pH scale to identify the pH of each solution. Record the name and pH of each solution.

**D** Place a few petals from one of the flowers into the mortar. Use a clean pipette to add about 1 $cm^3$ of ethanol. Use the pestle to carefully grind the petals and release the pigment into the alcohol. If the solution is not strongly coloured, add a few more petals and grind to release more pigment.

**E** Label a test tube with the name of the flower, and pour the coloured solution into the tube.

**F** Repeat steps D and E for each flower species.

**G** Using a clean pipette, place a few drops of one flower solution in wells of one row of the spotting tile – one well for each of the test solutions that you have.

**H** Rinse the pipette thoroughly, then add a few drops of the first test solution to one of the wells containing the flower extract.

**I** Repeat step H for each of the test solutions, adding each one to a separate well. For each well, record the name of the test solution and the effect, if any, on the colour of the flower pigment.

**J** Repeat steps H and I for each of the flower pigment solutions.

## Considering your results/conclusions

**2** Use your table to answer the following questions.
(a) Which pigment showed the greatest range of colours?
(b) Which pigment would be most useful for testing the pH change over a wide range of pH? Explain your answer.
(c) Which pigment would be most useful for testing the pH change of acidic solutions only? Explain your answer.

**3** Suggest how the method could be improved to help you give better answers to these questions.

# 2 Leaf fossils

Leaf fossils may form in several ways, including cast or mould impressions. These form when a leaf falls on sediment and is rapidly buried under other sediments. As the leaf is buried deeper and deeper, the sediment is compressed and changed into rock that forms a 'mould' over the leaf. If the leaf tissue is replaced by minerals (such as silica) before it decays, the minerals produce a 'cast' of the original leaf.

In this activity you are going to use leaves to investigate the effect of sediment texture on the quality of 'fossils' that are produced.

## Safety

Wear eye protection. Wash hands after making casts.

## Apparatus

'fossil dough' of fine and coarse types
leaves
hand lens or binocular microscope

## Method

**A** Choose two leaves of the same species

**B** Flatten a ball of 'fossil dough' of each type.

**C** Press one leaf firmly into the surface of each piece of dough.

**D** Carefully remove the leaves, and place each mould on a piece of paper, which is labelled with your name. The moulds will need 24 hours to harden.

**E** If you have sufficient leaves and dough, repeat steps A–D with a different species.

## Recording your results

**1** After 24 hours, use a hand lens or binocular microscope to look closely at your moulds. Record all the details you can see in labelled diagrams, also recording how clearly you can see the details.

## Considering your results/conclusions

**2** Compare the detail that you were able to see in each of your moulds.

**3** Use what you find to draw a conclusion about the effect of the fineness of the sediment on the detail that may be recorded in a fossil. Suggest what impact this has on the information that we can get from fossils found in rocks formed from different kinds of sediment.

**4** Use your knowledge of fossils to judge how good a model this method is for explaining how fossils form.

# 3 Seasonal photosynthesis

Photosynthesis is the set of reactions in plants in which light energy is used to convert carbon dioxide and water to food (glucose) and oxygen. In this activity you will look at the effect of changing daylight on photosynthesis in plants.

**1** The table below shows data on the rate of photosynthesis in a plant over a period of 24 hours. Use the data to draw a graph either by hand or using a spreadsheet program.

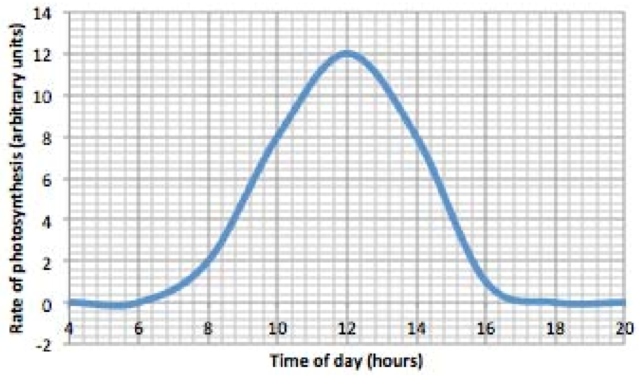
| **Time of day (hours)** | 0000 | 0300 | 0600 | 0900 | 1200 | 1500 | 1800 | 2100 | 2400 |
|---|---|---|---|---|---|---|---|---|---|
| **Rate of photosynthesis (arbitrary units)** | 0 | 0 | 4 | 14 | 30 | 28 | 18 | 5 | 0 |

Use your graph to answer the following questions.

**2** Describe the shape of the graph.

**3** Explain why the graph has this shape.

The graph on the right shows the rate of photosynthesis for the same plant in the same place but on a different day of the year.




**4** Compare this graph with the one that you drew. Identify a similarity and a difference between the graphs.

**5** Use your answer to Question 2 to help you explain:
(a) the similarity
(b) the difference.

**6** Use what you have learnt to suggest whether this plant is growing near to the Equator or nearer to one of the poles, such as in the UK. Explain your answer.

## Extension

Plants use much of the food that they make during photosynthesis for respiration. Respiration releases energy that plant cells need for carrying out all the life processes. Respiration continues all the time – if a plant does not have enough energy it will die.

**7** Use this information and your answers above to help you explain:
(a) why plants grow more rapidly near the Equator than at higher latitudes such as the UK
(b) why many plants growing at higher latitudes lose their leaves during the winter and regrow them in spring.

# 4 Is Spring getting earlier?

In this activity you will study an example of phenology – the effect of changing season on a naturally occurring activity.

You have been given a spreadsheet containing a long-term data set that shows the date of first flowering of snowdrops at one particular site in the UK between 1976 and 2012, and a temperature data set for the same years. The date of first flowering is given as the number of days since the start of the year. The temperature is the average January temperature for that year from the nearest available monitoring site.

Use the data to answer the following questions.

**1** Use the spreadsheet program to create a graph of the temperature data.

**2** Describe the shape of the graph, and identify any interesting features in it.

In order to identify any trend in the data, we need to make some calculations. A simple way to do this is to take an average of some data in different parts of the record.

**3** Use the spreadsheet to calculate the mean temperature for the following groups of years: (a) 1976–1980, (b) 1992–1996, (c) 2008–2012.

**4** Compare the values you get for each mean.

**5** Do you think that calculating the means like this is a good way to interpret any pattern in the data? Explain your answer.

Another method we can use is to calculate 'running means'. For this you calculate the mean value for each set of a number of years, e.g. 1976–1980, 1977–1981, 1978–1982 and so on. This helps to average out large amounts of variation in the data and can make it easier to see patterns.

**6** Calculate the running mean of each set of 5 years in the temperature data and use the results to produce a line graph.

**7** Describe the shape of the graph and identify any interesting features in it.

**8** Do you think that taking running means is a good way to interpret any pattern in the data? Explain your answer.

Most spreadsheet programs will automatically calculate a trendline on a graph. The trendline minimises the average distance of any point on the graph from the line.

**9** Add a trendline to the temperature graph that you created for Question 1.

**10** Compare the trendline with the conclusions that you drew for the other calculations. Do they show a similar pattern?

**11** Create a graph of the first flower data and use the method you think is best for identifying a trend in the data. Describe what you see.

**12** Compare your results from the temperature data and the first flower data and comment on any similarities or differences.

**13** Use your answer to discuss whether using first flower dates is a good indicator of the changing temperature of the environment.

# 5 Monitoring temperature

There are many different data sets of temperatures on Earth, produced by different scientific groups. The information below will help you to interpret a graph of several different data sets and to explain some of the differences between them.

## Direct measurements

Measurements of temperature at the Earth's surface have been made using thermometers since about 1850 in some parts of the world, and more recently in other places. Local surface temperature is affected by many factors in the environment, not only the time of day or year, but also the prevailing wind direction and weather pattern, as well as the amount of dust in the atmosphere. It is also affected by the type of vegetation; trees, for example, circulate a lot of water from the ground back into the atmosphere, which has a local cooling effect on the air. Large numbers of buildings and roads absorb more heat than the surrounding land and so increase the local temperature. Changes in some of these factors over time can mean that long-term trends in temperature may not all be the effect of climate change.

Radiosonde measuring is the direct measuring of atmospheric temperatures and other variables (e.g. wind speed, atmospheric pressure) using weather balloons. The gas in the balloon expands as it rises, because atmospheric pressure decreases, and eventually bursts. As it goes up, the sensors on the balloon send measurements to a ground receiver.

## Satellite measuring

Measurements from orbiting satellites have the advantage over direct measurements of giving global coverage, over oceans as well as over land.

Satellites don't actually measure temperature. Instead they measure the energy given out (e.g. as light waves, infrared waves) by the Earth. These energy measurements are called radiance. Different scientific groups analyse the data using different mathematical models that interpret the radiance values as temperatures at the Earth's surface and at different levels in the atmosphere. The different models produce slightly different temperature data sets. Two US data sets that are commonly quoted are UAH (University of Alabama in Huntsville) and RSS (Remote Sensing Systems). In the UK we have the Had (Hadley Centre, UK Met Office) data sets.

The data also have to be adjusted over time as the sensors on the satellites get older, and when a new set of sensors on a new satellite takes over from an old satellite.

The interpreted temperature data are used in computer modelling to predict weather patterns, including extremes, the local effect of cities, living by the sea or in the middle of a continent. They are also used to predict long-term trends in global warming and potential climate change.

## Differences in trends

Interpretation of the different data sets gives slightly different estimates of long-term trends in temperature change. For example:

- Surface measurements give a trend of an increase of about 0.07 °C per decade calculated over the past century and an increase of 0.17 °C per decade in data since 1979.
- The Hadley Centre shows average global temperatures have increased at a rate of more than 0.15 °C per decade since the mid-1970s.
- The RSS data set gives a trend of +0.137 °C/decade, and the UAH data set gives a trend of +0.136°C/decade.

## Exploring Science Extra 6: Spring flowers

| Year | Snowdrop first flower (number of days after 1st January) | Central England Temperature (January) (°C) |
|---|---|---|
| 1976 | 21 | 5.9 |
| 1977 | 33 | 2.8 |
| 1978 | 50 | 3.4 |
| 1979 | 61 | -0.4 |
| 1980 | 30 | 2.3 |
| 1981 | 27 | 4.9 |
| 1982 | 32 | 2.6 |
| 1983 | 17 | 6.7 |
| 1984 | 29 | 3.8 |
| 1985 | 34 | 0.8 |
| 1986 | 64 | 3.5 |
| 1987 | 37 | 0.8 |
| 1988 | 26 | 5.3 |
| 1989 | 21 | 6.1 |
| 1990 | 30 | 6.5 |
| 1991 | 49 | 3.3 |
| 1992 | 34 | 3.7 |
| 1993 | 18 | 5.9 |
| 1994 | 21 | 5.3 |
| 1995 | 24 | 4.8 |
| 1996 | 41 | 4.3 |
| 1997 | 32 | 2.5 |
| 1998 | 13 | 5.2 |
| 1999 | 20 | 5.5 |
| 2000 | 20 | 4.9 |
| 2001 | 24 | 3.2 |
| 2002 | 28 | 5.5 |
| 2003 | 21 | 4.5 |
| 2004 | 21 | 5.2 |
| 2005 | 7 | 6 |
| 2006 | 20 | 4.3 |
| 2007 | 13 | 7 |
| 2008 | 23 | 6.6 |
| 2009 | 26 | 3 |
| 2010 | 34 | 1.4 |
| 2011 | 34 | 3.7 |

| | | |
|---|---|---|
| 2012 | 22 | 5.4 |

Data as provided courtesy of the Woodland Trust Nature's Calendar project, collected by Anne Phillips in the West Midlands