Plant Science Outreach Demonstrations

How to Use This Guide

This guide provides instructions for two hands-on plant science demonstrations that can be delivered as part of a science outreach event. They could be presented as part of a public event or taken into schools and require only a table and a few easy-to-obtain pieces of equipment. They are designed to be delivered to small groups (about 3-5 people). The target age group is children 8-12 years old but can be adapted to suit different ages and levels of expertise.

Instructions for the demonstration, including suggestions for questions you might ask are written in italics. Information for the benefit of you, the demonstrator, is not italicised and this includes background information that you will want to deliver to your audience. Quite a lot of information is given, allowing you to adapt your delivery to the level of knowledge of your audience (tip: ask lots of questions to start with, to gauge this). This background information should also allow anyone with some scientific background (you don't have to be a botanist!) to deliver the demonstration.

Stickers/ Badges

Your audience have a lot of information to take in during one of these demonstrations, so you may want to reward them with a sticker! On the final pages are some cute plant scientist and gardener/ farmer cartoons that you can print off and use to make badges or stickers, if you wish.

An Introduction to Wildflower I.D

Lots of people love wildflowers but don't know how to identify them. Often, they are too scared to start, intimidated by the huge number of different species and complicated-sounding Latin names. This demonstration will show members of the public that some basic identification can be easy! It can be used to show them the most obvious features that differentiate some of the major flowering plant groups and hopefully may inspire the next generation of botanists.

Before You Start

Make sure you are aware of the laws surrounding harvesting wildflowers before going out to pick them.

If you are in the United Kingdom, the rules are as follows

It is not illegal to pick most wildflowers for personal, non-commercial use. Legislation under the Wildlife and Countryside Act (1981) makes it illegal "to uproot any wild plant without permission from the landowner or occupier" in Britain, where 'uproot' is defined as "to dig up or otherwise remove the plant from the land on which it is growing". Therefore, you can pick parts of a plant (leaves, flowers etc. stems), so long as you do not uproot the whole thing. Note that it is important that this is from public land or you have permission from the landowner, otherwise it qualifies as theft.

When you should not pick anything from the plant (without seeking prior permission):

- If the site is designated for its conservation interest, such as National Nature Reserves (NNRs) and Sites of Special Scientific Interest (SSSI's).
- If there are by-laws in operation that forbid picking plants, for example on Nature Reserves, Ministry of Defence property or National Trust land.
- If the plant is listed as highly threatened by the Wildlife and Countryside Act. These include several orchids, alpine sow-thistle and wild gladiolus (full list at https://www.legislation.gov.uk/ukpga/1981/69/schedule/8)

Some ideas for where to obtain flowers:

- Gardens – your own, school/ college/ university
- Weeds growing by the roadside or in fields (e.g. *Arabidopsis* (Brassicaceae), deadnettle (Lamiaceae), dandelions (Asteraceae))
- Buy from a shop – although these will be cultivated varieties, bouquets often include examples from Asteraceae, monocots (e.g. lilies, daffodils); you could also buy food plants such as peas (Fabaceae) and mints (Lamiaceae), to illustrate some of the features

Kit List

- **Cups of water**
- **Magnifying glass**
- (optional) **Stereomicroscope**
- (optional) **Tweezers** (for dissecting flowers)
- **Example images and diagrams of plants**
- (optional) **A wildflower ID guide** (in case your audience are particularly interested and have further questions)
- **A range of wild flower samples**: whatever can be readily obtained in the local area. This will be season-dependent. Common examples that can be found in the UK are given below. It's best to get a good range. Pick them shortly before you start demonstrating so that they don't wilt too much. For whole shoots, place them in a cup of water to keep them fresh. This guide is written so that a non-botanist could deliver it, however it would be useful if someone with some knowledge of local flowers can help collect and identify samples.

Explanation and Delivery

Spread the samples and images out on a table, grouping together plants from the same family. If you have lots of different examples from one group, keep a few aside for a test later.

Suggested prompts to start:
Can you name me some flowers?
Can you tell me what any of these flowers are?

Then move on to explain about the characteristics that distinguish different plants.

Don't feel you have to go through all the different groups! Several are listed, so the demonstration can be adapted depending on what is available. How many you talk about and how much detail you go into can be adapted depending on the age and level of interest.

Monocots vs dicots

Examples:

- Monocots
    - Grasses, tulips, daffodils, lilies, bluebells, palm leaves
- Eudicots
    - Any from the groups below

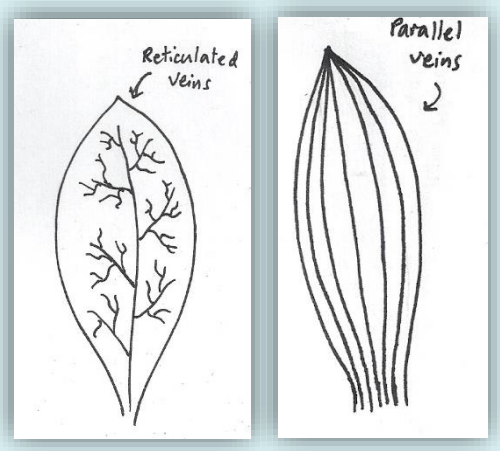
Most of the flowering plants are split into two major groups: the monocots and the eudicots. The name refers to the number of cotyledons (the first leaves produced by the embryo when it germinates). Monocots have one cotyledon (hence the prefix “mono”) while eudicots have two (hence “di”).

There are several differences in form between the two types of plant.

Take 2 or 3 samples from each group. Ask if they can see any features which are shared within the group but differ between the groups. If they need a prompt, suggest counting the parts of the flower. For smaller flowers, it may be easier to look at the flowers under a stereomicroscope.

The features that are most noticeable are:

- Number of floral organs (stamens, ovules, petals)
    - In monocots, these occur in multiples of 3
    - In eudicots, they occur in multiples of 4 or 5
- Leaf veins
    - In monocots, the veins run parallel
    - In eudicots the veins are reticulated (they form a web-like pattern)



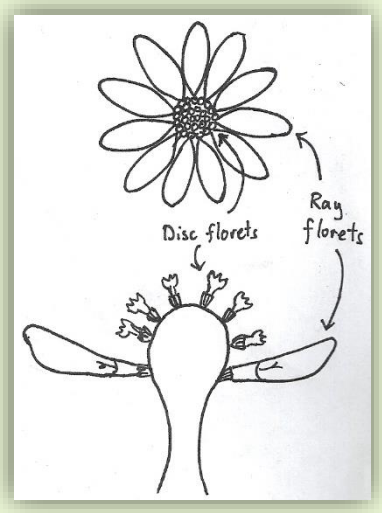
Other information:

- Monocots and eudicots also differ in the structure of their vasculature (the vein-like vessels that transport water and nutrients). In monocots, bundles of vessels are randomly scattered throughout the stem. In eudicots they are arranged in a ring-like pattern. It is possible to buy or make microscope slides of stems so if you’re lucky enough to have access to such slides and a microscope, you can show them this feature as well.

The following pages describe some of the major groups of flowering plants. The groups are named with reference to a well-known member of that family (e.g. cabbage family, carrot family). Latin names are also listed which can be introduced if the audience is a bit older and interested. If the group has an alternative name (with which some adults may be more familiar) this is given in brackets.

Daisy Family - Asteraceae (Compositae)

Examples: daisies, ragwort, dandelions, thistles



Distinctive features:

- Composite flowers

The Asteraceae have composite flowers: what looks like one flower is actually composed of lots of small flowers. This is called an inflorescence. Consider a daisy: the central yellow part is called the disc and each little blob is one flower (a disc floret). Each white petal belongs to one flower positioned around the perimeter of the disc – these are ray florets.

Take a plant from this group and ask them to count the number of flowers. If they just give the number of inflorescences, explain that these flowers are, in fact, they are composites, and each "flower" actually contains lots of tiny flowers! This is a good one to look at under a microscope or magnifying glass if you have one.

Other facts:

- This is the world's largest family of flowering plants, with c.23,000 species

Cabbage Family – Brassicaceae (Cruciferae)

Examples: Arabidopsis, oil seed rape, watercress, mustard

Distinctive features:

- 4 free (usually equally-sized) petals arranged in a cross-shape.
- 6 stamens, usually 2 are shorter than the other 4 (this will be clearer under the microscope/ magnifying glass)
- Their seeds are often contained in long, thin seed pods, called siliques
- Pungent "cabbagey" smell when leaves are crushed. This smell is due to the release of mustard oils. These are produced from chemicals called glucosinolates when the plant is damaged. Their unpleasant taste deters herbivores.

Ask them to look at the flowers. What shape does it remind them of? Ask them to count the petals and stamens. Break up the leaves – is the smell familiar? Is it a nice smell? Do they like to eat cabbage? If no, then they're not the only one! That's because this family produce bitter chemicals to deter animals from eating them and this is what you can smell.

Other facts:

- Many of our vegetables come from this family, including broccoli, cabbage, cauliflower and kale. Interestingly these four vegetables, despite looking very different, all belong to the same species – *Brassica oleracea*. Selective breeding has made them look very different (if they find this hard to believe, point out the large differences between dog breeds, which has similarly been achieved by selective breeding).
- Brassicas are some of the fewer flowering plant species that do not interact with fungi (known as mycorrhiza) to obtain nutrients such as phosphate and nitrate.
- *Arabidopsis thaliana* (thale cress) is a brassica and a common weed. However, it is very important to science. It's what we call a "model organism": an organism that lots of basic scientific research is conducted on (other examples are the fruit fly and yeast). It has become very popular because it is small, grows quickly and has a small genome. This makes it convenient to work with.

Mint Family – Lamiaceae (Labiatae)

e.g. water-mint, peppermint, spear mint, red and white deadnettle

Distinctive features:

- Square stems
- Leaves in pairs, opposite each-other
- Often scented when crushed
- Flowers are bilaterally symmetrical (one line of symmetry down the middle) and petals are often fused

Ask them to crush the leaves of a mint plant. Is the smell familiar? Can they think of any other plants with nice smells and tastes, which they might find in the kitchen? Why might it be useful for plants to smell/ taste like this?

Other facts:

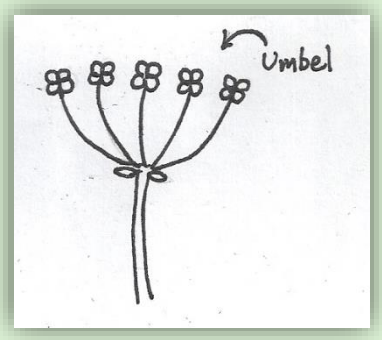
- Many of our culinary herbs belong to this family: mint, basil, rosemary, thyme, sage and others. This is because many lamiates produce scented oils. This might be to deter feeding by herbivores

Carrot Family – Apiaceae (Umbelliferae)

Examples: wild carrot, hogweed, cow parsley

Distinctive features:

- Flowers arranged in umbels. An umbel is an arrangement of flowers in which stalks of nearly equal length, each terminating in a flower, grow from a common centre and form a flat or curved surface.

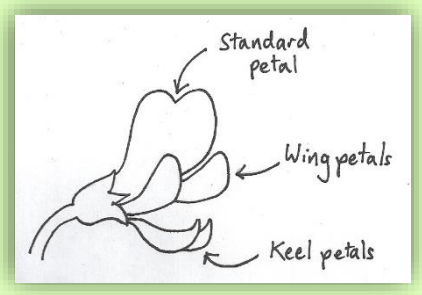


Pea Family – Fabaceae (Leguminosae)

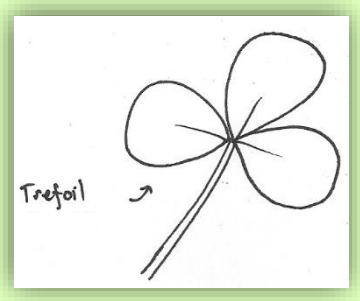
Examples: gorse, lupins, clover, tufted vetch, common vetch

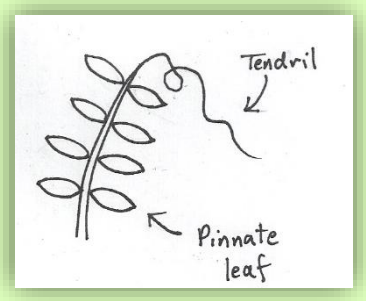
Distinctive features:

- Flower shape:
    - Bilateral symmetry (only one line of symmetry, down the middle of the flower)
    - 5 petals with 2 at the bottom, often fused, to form a boat-shaped "keel"; 2 "wing" petals at the side, one wide petal at the top (often erect)



- Seeds (beans/ peas) held in pods
- Clovers have trefoil leaves (made of three parts)
- Vetches and peas often have tendrils and many pairs of pinnate leaves





Other facts:

- Legumes are an excellent source of protein
- Legumes have nodules in their roots that house special bacteria called Rhizobia. These convert nitrogen into nitrate, which the plant needs to grow. Because of this, legumes are often planted to increase soil fertility.

An extra challenge:

If you set aside some plants at the beginning, challenge your audience to use their new knowledge of plant ID to match the plants to the right group! Alternatively, conceal the names on the images provided and use those.

Other Resources

There are a number of resources available in books and on the internet if your audience (or you!) want to learn more.

For the UK, the charity Plantlife has a great website (https://www.plantlife.org.uk/uk) and a good book for wildflower ID is Francis Rose's "The Wild Flower Key", published by Frederick Warne Books

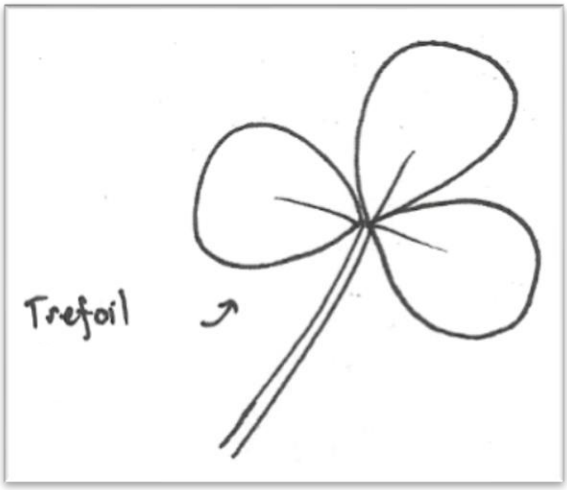
Images and Diagrams

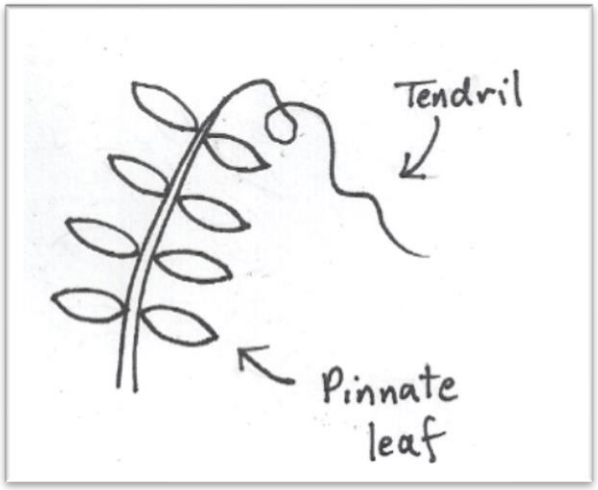
You may not be able to find enough good specimens of different groups so these images and diagrams are provided to illustrate some of the key features. You may wish to print them off, cut them out and laminate them.

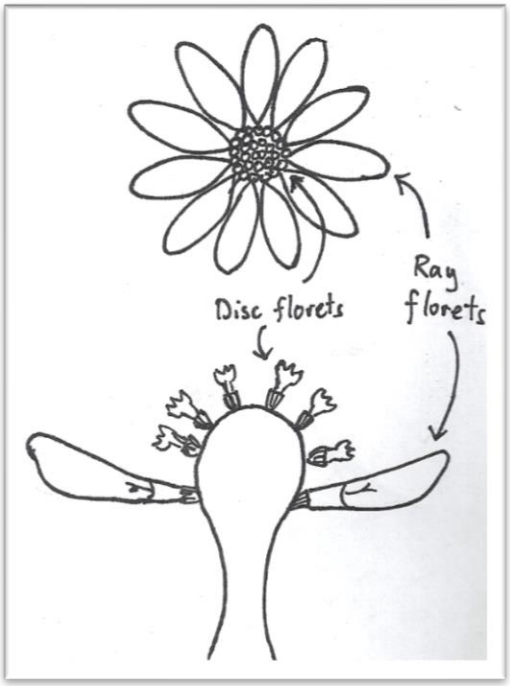

Arabidopsis Flowers (Brassicaceae)
Credit: Alberto Salguero Quiles

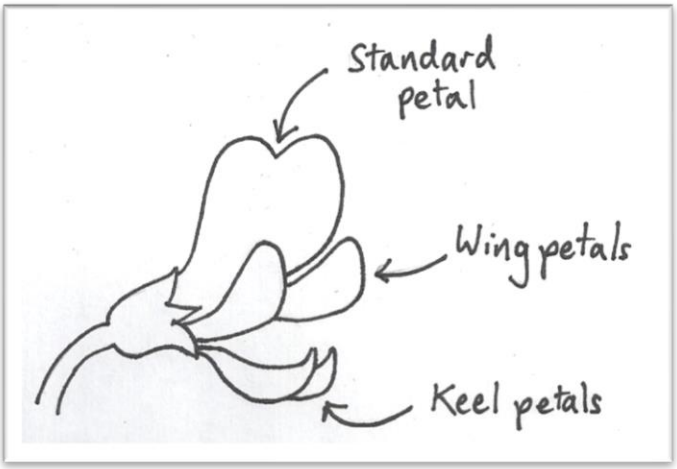

Red Deadnettle (Lamiaceae)
Credit: Melissa McMasters

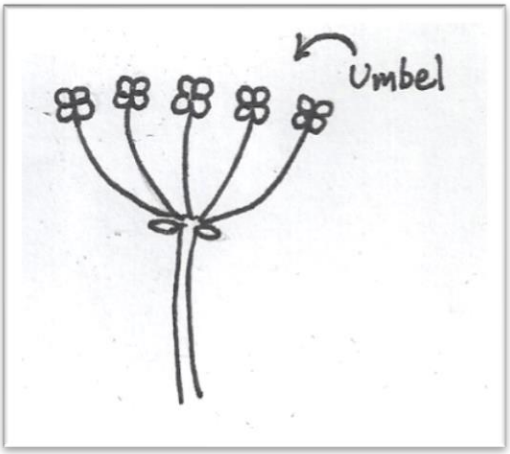

Daisy (Asteraceae)
Credit: Leslie Seaton

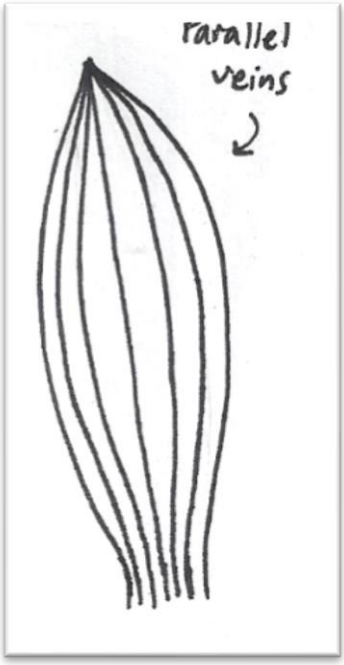

Trefoil


Tendril
Pinnate leaf


Disc florets
Ray florets


Standard petal
Wing petals
Keel petals


Umbel


Parallel veins


Reticulated veins

Don't Eat Me! : Exploring Chemical Defences

The aim of this demonstration is to teach your audience about some of the diverse protective chemicals that plants produce and how we can use them. It largely focuses on food crops that most members of the public are probably familiar with. It is split into two parts. You can pick and choose from them, depending on how much time you have.

Part 1: Plant pH

Many plants produce acids. These help to stop animals (herbivores) from eating them, because the acids have unpleasant tastes and can cause uncomfortable sensations. In this part of the demonstration, participants test different leaves to find out how acidic they are.

Kit List

- **Gloves**
- **Mortar and pestle**
- **Strips of Universal Indicator paper** (or use dilute UI solution)
- **UI colour chart**
- **Water**
- **Coverslips**
- **A variety of different leaves** including some that are acidic (e.g. geranium, nettle, dock) and some that are not (e.g. holly, ivy, grass)

Explanation and Delivery

To introduce the demonstration:

Did you know that some plants contain acid? Can you name any plants that do? (they are most likely to mention citrus fruits).
Why do you think they might contain acid?
Ask if they understand the concept of pH. If they don't, explain it:
pH is a measure of how strong an acid is. The scale goes from 1 to 14. Anything below 7 is acidic, and the lower the number, the stronger the acid. We can work out where on the scale a substance lies by adding a special chemical called an indicator. The indicator changes colour depending on what pH the substance is.

Instructions:
Take a leaf or two from one plant. Tear into pieces (wearing gloves if it is harmful to touch e.g. holly, nettles).
Place the pieces of leaf in a mortar along with a teaspoon or two of water and ask the participants to grind them up well.
Ask them to dip a strip of UI paper into the ground-up plant mixture (or add a few cm^3 of dilute UI solution, if using)
Ask them to compare it to the chart - what pH is it? Does that mean that the plant contains acid?

A follow-up experiment with the stinging nettles:
Take an intact leaf and press its underside against a damp UI strip. Place a coverslip over the top and press on it to crush some of the needles.
Yellow spots will appear on the strip where the needles have been broken.
What pH is the liquid that has been released from the nettle stings?

Nettle stings are glass needles coated in a mixture of different chemicals that include formic acid and histamine. Histamine is a chemical we naturally make in our bodies and causes inflammation.

If acid is so great at deterring herbivores, why don't all plants contain acid?
Discuss how some plants aren't at as much risk from herbivores, depending on where they grow, so it's more important to invest energy in growth and making seeds. Others use different ways to defend themselves. Can they think of any other ways plants might stop animals from eating them?
(they might mention spines, on cacti, holly etc., or plants that are tall and put their leaves out-of-reach of herbivores).

Part 2: Taste and Smell

Lots of the distinctive properties (especially tastes and smells) of plants that we eat are intended as herbivore defences. In this part of the demonstration, you will get your audience to identify different foodstuffs and materials by smell, taste and touch to teach them a bit about the chemistry and ecology of plant defences.

Kit List

- **Tea leaves**
- **Coffee beans* or granules**
- **Cabbage**
- **Mint/ other herb leaves**
- **Mint sweets***
- **Dried chilli flakes***
- **Latex balloons/ anything else made from natural rubber**
- **Cups**

*Depending on where you're demonstrating and to whom you're demonstrating, you may not be allowed to let members of the public taste foods that are not individually wrapped. This will be possible for the sweets, but for others you may have to rely on smell.
Before starting, check that none of the participants have allergies to any of the foods or latex.

Explanation and Delivery

Place each of the food samples into a cup. For the cabbage and herbs, break up the leaves so they release their fragrance and are more easily identifiable. For each sample, tea through to mint, ask your audience to smell and try to identify the food. For the chillies and latex, they may have to identify by touch and sight. For touch identification, you may wish to put the samples in boxes with opening for hands only, so that they don't see the samples first. Once they have identified something (or you have revealed it) proceed to give more detail:

Tea/ Coffee – Tannins and Caffeine

Ask them to taste the coffee/ recall a time they have tasted it. What does It taste like?

The bitterness of tea and coffee (and also red wine) is caused by compounds called tannins. The taste isn't the tannins themselves: they cause the proteins in our saliva to come out of solution (precipitate), which creates a bitter taste and a drying sensation in the mouth. This is unpleasant for herbivores and so deters feeding. They might also act as pesticides.

What else do you associate with tea or coffee? Hint: it's also in cola? It's the reason why you shouldn't drink any of these things too late at night.
Tea and coffee famously contain caffeine. This is a type of chemical called an alkaloid, which are toxins. Several other familiar drugs are alkaloids (such as morphine from poppies and nicotine from tobacco). Caffeine is a mild drug that makes you feel more awake and if you have too much can give you "the jitters (for older participants you could mention that it is a stimulant of the central nervous system). For tiny insects, however, caffeine can cause paralysis and death and this stops the plant being eaten.

Cabbage – Glucosinolates

Do you like the taste of cabbage? If you don't, you're not the only one! The smell and taste that cabbages and other plants in the same family produce is meant to taste bad, so that animals don't eat them.

The pungent "cabbagey" smell when leaves are crushed is caused by the release of mustard oils. These are produced from chemicals called glucosinolates when the plant is damaged. This is because mustard oil production requires a chemical reaction to take place between a glucosinolate and a specific enzyme (a biological catalyst) and these are stored in separate compartments. Only when the tissue is damaged do the enzyme and chemical meet and produce the mustard oil.

A similar process controls the production of hydrogen cyanide. Your audience may be surprised to learn that several thousands of plant species produce cyanide (a famously very poisonous substance), including cassava and almonds. In several domesticated varieties, however, selective breeding has eliminated cyanide production or reduced it to very low levels.

Mint – Volatile Oils

Do you like the smell? Well, if you were an insect you probably wouldn't!

Peppermint oil contains lots of different chemicals, including natural pesticides. The aroma can repel some insect pests, including mosquitos.

How does your mouth feel when you taste it?
Mint creates a cold sensation in the mouth. This is because menthol, a chemical in mint oils, can activate a receptor protein in our mouths (called TRPM8) that senses cold temperatures.

Chillies – Capsaicin

Who likes spicy food? How does your mouth feel when you taste it?

Chillies contain a chemical called capsaicin and this is what creates the burning sensation. This acts in a similar way to menthol in mint: it activates receptors in our bodies (called TrpV1) that normally respond to heat. These receptors are found in all mammals, so they stop mammalian herbivores from eating the fruits. However, the counterpart of these receptors in birds do not bind capsaicin and therefore they can happily eat the chilli peppers. This is good for the plants, because the birds will fly away and disperse the seeds far and wide.

The spiciness of chillies is measured by the Scoville scale: concentrated capsaicin is 18 million; jalapenos are around 2,000.

Latex – Rubber Trees

Have a go at feeling and stretching the balloons. This substance feels artificial but it actually comes from plants!

Latex (rubber) is used to make party balloons, mattresses and all sorts of other useful things. It is a milky fluid that contains lots of long molecules (polymers). When a plant is attacked by insects, the latex is released and its stickiness traps the insects and gums up their mouthparts. The latex often contains unpleasant-tasting substance as well. Some insects sneakily avoid this by biting the veins of the plant and draining the latex.

Extra - Plants and Medicines

Lots of chemicals produced by plants are also important medicines, for example:

- Poppies produce morphine, a painkiller
- *Artemisia annua* is the source of the antimalarial drug, artemisinin
- The Madagascar Periwinkle is the source of the anticancer drugs vincristine and vinblastine

However, obtaining these chemicals from plants can be quite difficult and expensive, often requiring lots of plant material to obtain a reasonable amount of the drug. Because of this, there is lots of research being done to increase the yields of the drugs (or their precursors) in the original plants (by breeding and genetic engineering). Some groups are also trying to genetically modify yeast to produce important drugs or similar chemicals. If this works, the drugs could be produced much more quickly and cheaply.