



Science on the Shelves Project

'Eggsperiments' Activity Sheet

In this activity, you can:

- learn how to test an egg for freshness,
- discover the secret to making a fresh egg float,
- find out how to shell a raw egg and
- learn what links eggshells, caves, kettle scale and acid rain.

Please follow any **safety instructions highlighted like this in red.**

Is your egg fresh?

There's an easy way to tell if an egg is fresh or not and you don't have to break it open either! Carefully lower your eggs into fresh cold water using a spoon (you can do this in the pan if you're about to boil them). If the eggs stay at the bottom they're fresh; if the eggs float, however, they're stale and best avoided.



Make your fresh egg float

So, if a fresh egg sinks, how can I make it float? (and no, leaving a fresh egg long enough to go off doesn't count!)

You can make a fresh egg float by dissolving salt in the water first. In fact, you can do an experiment to find out how much salt you need to add before the egg floats. Use a measuring jug of water and see how many tablespoons of salt you dissolve in the water before the egg starts to float.



Water can only hold up things if they are lighter than the same amount of water – water can only hold up itself or any stuff lighter than itself. Such stuff is described as being *less dense than water* and it floats (for example, a piece of cork). Alternatively, stuff heavier than water is described as *more dense than water* and it sinks (for example, a coin).

When a stale egg floats, it does so because the water is holding it up. If a stale egg floats in pure water it must be less dense than the water itself, whilst a fresh egg that sinks must be more dense than the water. Can you think why a stale egg would be less dense than a fresh egg?

Floating and sinking eggs – the science bit

As an egg ages, the water inside the shell slowly evaporates and is replaced by air, or by any gases that are produced as the egg rots (phew!). Many food products (vegetable, fruit, animal, etc.) give off gases when they go off, and they often smell! Eggs have such a distinctive, unpleasant smell when they go off that we talk about something “smelling like rotten eggs” (special precautions have to be taken at domestic waste tips to deal with the gases produced as rotting sets in). Anyway, as the egg gets older it ends up with more gas inside and less water, and the gas is lighter than the water. Overall, this makes the egg lighter and in fact less dense than water so that a stale egg floats.

Time for some more work for you: how do you know that a gas is lighter than water?

Now to the fresh egg which *does* float in salty water! You’re probably getting the picture by now: a fresh egg sinks in pure water because it is more dense than the water, but can float when the liquid itself has increased in density. This happens when salt is dissolved in the water – the density increases and eventually exceeds that of the egg. You may have noticed yourself that it is easier to swim in the salty water of the sea compared with the water in a swimming pool or freshwater lake. That’s because the salty water helps you to float.



Further investigations

Can you think of anything else in the kitchen cupboards which would have the same effect as the salt? Which way up is the floating egg? Is it always this way? Do you know why?

How to shell a raw egg



Try soaking your egg in vinegar! Place a raw egg in a glass, cover it completely with vinegar and leave it for a couple of days. Not that hard and neither is the egg – look how squishy ours was! So what’s going on? And what’s it got to do with caves, kettle scale and acid rain?

By making some careful observations yourself, you can help work out what’s going on. For instance, what do you notice on the surface of the egg as it sits in the vinegar? (It might be easier to see if you use colourless spirit vinegar rather than dark brown malt vinegar.)

What's happening to the egg shell? – the science bit

What you can see are bubbles of the gas **carbon dioxide**. We breathe out carbon dioxide and the same gas is produced by burning fossil fuels, contributing to the **greenhouse effect**. But where has this carbon dioxide come from? The egg shell itself – the hard shell is made of a material called a **carbonate**, which contains both carbon and oxygen atoms.



Carbonates can be converted to carbon dioxide when they come into contact with materials known as **acids**. Vinegar is an acid (it's a dilute solution of acetic acid) and it converts the carbonate in the egg's shell to molecules of carbon dioxide gas. Each molecule of carbon dioxide has one carbon atom attached to two oxygen atoms, which is why it is sometimes referred to using the molecular formula, CO_2 (pronounced "see oh two").

Another acid you can find in a supermarket is citric acid (chemists and home-brew suppliers also sell it). This is the purified, crystalline acid from citrus fruits, such as oranges, lemons and limes. You can make a concentrated solution of it in water that is stronger than the acetic acid in vinegar. This dissolves the egg shell more quickly, more completely and with less smell. You can find out more about acids in our activity The Acid Test.

Eggshells, caves, kettle scale and acid rain

In limestone regions, the rocks are made out of a form of calcium carbonate (mainly a mineral known as calcite), which is similar to egg shell. In fact, limestone rocks began their lives as the shells of marine organisms which accumulated to huge depths at the bottom of prehistoric oceans. Compressed into rocks over millions of years and raised upwards, they became the familiar limestone landscapes of areas like the Yorkshire Dales and Cheddar Gorge. Like eggshell then, limestone is attacked by acids and the role of acid is played in this case by rain water.

Rain water is acidic because of the carbon dioxide gas in the atmosphere (yes, that again!) which dissolves slightly in the water to make a weak acid called carbonic acid. The action of this acid causes the limestone itself to dissolve slightly, releasing minerals into the water and causing a number geological features typical of limestone country such as caves, stalactites and stalagmites. The formation of stalactites demonstrates that the process of dissolving limestone is reversible.

Stalagmites and stalactites

Drops of water on the ceiling of a limestone cave contain dissolved limestone rock. As the drop hangs there, water and carbon dioxide gas slowly evaporate from it leaving a small lump of limestone behind. This is the exact reverse of the process by which the limestone was dissolved initially by the rain water (carbonic acid). Another drop can now run down the lump and it too leaves behind a bit of limestone. Over time, fingers of limestone grow down from the ceiling. In a similar way, stalagmites begin to grow where the drips from the ceiling hit the cave floor. Eventually a stalactite can meet a stalagmite to make a pillar.



Look into the bottom of your kettle!

You can see this process in action in your own home if you live in a region with hard water. Hard water is water with lots of minerals dissolved in it and it usually originates from limestone areas in exactly the way described above. Heating hard water has the same effect as the evaporation process during stalactite formation: it drives the water and carbon dioxide away from the dissolved limestone, which is re-deposited as solid calcium carbonate.



If you live in a hard water area, you only need to look inside your kettle to see your very own limestone landscape! Usually limestone is encrusted all over the element, the hottest part of the kettle. This can make your kettle very inefficient at boiling water so someone in your house probably cleans away this scale from time to time.

Using your knowledge of limestone, can you think what kind of material would be used to achieve this?

An acid, of course! Since you want to clean your kettle pretty quickly you need to use an acid that is stronger than vinegar but not so strong as to dissolve the kettle as well as the scale!



Many descaling products make use of citric acid as their active ingredient. You may also come across sulfamic acid used for the same purpose. Both are white solids that can be dissolved in water to make acidic solutions. Descaling products should be treated with respect and carry warnings about handling and usage. When added to a kettle that has scaled up, the carbon dioxide comes off in a dramatic, fizzing fashion. **You must keep clear, as the bursting bubbles throw up fumes and acid drops that you mustn't let near your skin, eyes or face.**

It never rains, it pours



Rain water can also be acidic because of atmospheric pollution from cars, industry and power stations burning fossil fuels. These produce gases more acidic than carbon dioxide, containing sulfur or nitrogen atoms in combination with oxygen atoms. Rain which has become acidic owing to such pollution is described as **acid rain** and has a significant effect on the environment.

Because limestone reacts with acids it provides a means of tackling acid rain. Limestone can be used as a scrubber in power station chimneys where it removes the acidic gases. However, this produces even more carbon dioxide which is a concern because of its contribution to the greenhouse effect (rather than its acidity). In addition, the limestone is produced and transported (more carbon dioxide!) from huge unsightly quarries often in areas of outstanding natural beauty such as the Derbyshire and Yorkshire Dales.



Science on the Shelves Project

‘Fun with Flour’ Activity Sheet

In this activity, you can:

- learn how to make glue,
- learn how to make paint,
- learn how to make play dough and
- learn how to make salt & water dough, all from flour!

Please follow any **safety instructions highlighted like this in red**. Before trying out any of these recipes you should have a responsible adult on hand and this will probably be the person whose kitchen you are using! This is even more important if you are going to use a recipe that involves cooking.

You'll notice that there's often a version that requires cooking and one that doesn't. In general, the cooked recipes produce thicker, smoother products that are less prone to going mouldy and smelly in a short time. But even so, it's best to store all products in sealed containers or freezer bags in the fridge (don't forget to label them) and to make small quantities freshly rather than large batches.

Flour and water glue, cooked

Boil 5 cups of water in a pan. Separately, in a bowl, mix 1/4 cup of sieved flour with a cup of cold water. Mix to a smooth consistency (this bit is like making custard or a white sauce) and when all the lumps have gone, add the mixture to the water in the pan. Gently boil, stirring continually for 2-3 minutes until the mixture thickens.

Allow to cool before using.

You can make a thicker glue (that has the benefit of drying more quickly) by using 1 whole cup of flour to every 3 cups of water.

Flour paste, uncooked

Mix 1/2 cup white flour and 2/3 cup water together to a paste with a creamy consistency. Add water by the drop or flour by the teaspoon to improve consistency and help avoid lumps. A few drops of peppermint oil have been suggested as a preservative, preventing the growth of mould.

Paint, cooked

Heat 1 cup of flour and 2 cups of water gently in a pan over a low heat with constant stirring until thickened. Allow to cool. Mix in drops of food colouring until you get the desired colour. You can scale up this recipe, dividing it into batches before adding different colours to each.

Play dough, cooked



First, you'll need to assemble the following ingredients:

- 2 cups white flour,
- 2 cups water,
- 1 cup salt,
- 2 tablespoons vegetable oil,
- 1 tablespoon cream of tartar,
- 1 teaspoon food colouring (optional).

Stir all the ingredients together in a pan over medium heat until the dough begins to pull away from the side of the pan. Remove from the heat and allow to cool. When cool to the touch, knead the play dough for a few minutes. Make sure it's stored in an airtight container, preferably in the fridge. You can add a few drops of food colouring to make different colours.

If you want to try your hand at making silly putty as well as play dough, we have a recipe for silly putty in our Let's Get Physical activity.

Play dough, uncooked

You can prepare the play dough from the same recipe without cooking if you replace the 2 cups of water with 2 of boiling water. **This still requires the utmost care and attention from a responsible adult.** In this case, first sift the dry ingredients together. Separately, mix the oil, water and food colouring together. Gradually add the hot liquid to the dry ingredients, mixing with a wooden spoon until a soft dough forms. When this is firm enough and cool enough, you can remove it and knead as above.

Salt and water dough, uncooked

This kind of dough is ideal for making decorations that you might wish to detail further and keep.

Mix thoroughly $\frac{1}{4}$ cup of salt, $\frac{1}{4}$ cup of water, and 1 cup of flour. Work into a very smooth dough using a wooden spoon and then your hands. Use biscuit cutters and a table knife to cut out the shapes you want. The dough will harden over 24 hours, after which it can be painted or covered with glitter. If you want to thread your decoration, make sure you make a hole before the dough hardens!





Science on the Shelves Project

‘Celery Rocks!’ Activity Sheet

In this activity, you can:

- learn how to dye a piece of celery like a stick of rock and then,
- find out what this tells us about how plants transport water.

How to make your celery rock



Blackpool rock, made from celery?

Well, not quite, but you can customise your own celery with stripes of colour running along its length just like the lettering in a stick of rock. It's best to use a short piece of celery with the leaves still on and place it in a few centimetres of food colouring in water. Leave it for a day or so then carefully cut into the celery to see where the colour has reached.

Have a look at the one we prepared earlier, using red food colouring:



You could split the celery lengthways along the lower half and place each side in a different colour to make your own multi-coloured celery stick!

Here's one we did with red and green food colouring:



The science bit – how plants transport water

One of the reasons that even wet summers can still end in drought is the efficiency of plants at moving water from the ground to their upper reaches where it evaporates from the surface of the foliage. The process is called **transpiration** and it's essential for moving water to all parts of plants, even to the tops of the tallest trees. The experiment with a stick of celery reveals that this happens through special tubes, called **xylems**, which take up the food colouring.

The process is accelerated by evaporation from the celery leaves and you can make it go even faster by using a hairdryer on the leaves. Compare the rate at which the colour is taken up between three celery sticks: one with no leaves, one with leaves, and one with leaves applying a hairdryer. Using the hairdryer simulates a warm, windy summer's day when water in the ground from a recent downpour can soon find itself being transpired back into the atmosphere.

You can imagine with the tallest trees that each water-carrying xylem contains a continuous, thin column of water over a hundred feet in length and reaching from the roots to the uppermost leaves. The effect of evaporation at the top of the tree literally pulls this column of water up the tree. The ability of these thin columns of water to be pulled in this way – without breaking – is attributed to the special forces between the water molecules in the liquid; this is called **capillary action**.



Science on the Shelves Project

'Go Green' Activity Sheet

In this activity, you can:

- learn what recycling is all about,
- discover why biodegradable packaging can be made from starch,
- find out the twelve principles of green chemistry and
- try your hand at our recycling wordsearch.

Please follow any **safety instructions highlighted like this in red.**

What is recycling?



***"I've never understood why all those humans
get rid of all the tastiest bits!"***

Most people are familiar with recycling but often we forget it means more than just throwing the odd empty can of pop or glass bottle into a recycling bin. Recycling is a multi-stage process which involves many people and many different processes:

1. People collect their recyclables and take them to collection points, or they sort their recyclables for a regular doorstep collection.
2. Companies must sort and process the materials collected, clean them up and sell them to manufacturers for reuse to make new products.
3. Finally, people must want to buy the new products made from recycled materials.

Recycling is a great thing to do, but it still uses energy and itself produces waste. We can all play our part in saving the environment by avoiding using excessive amounts of packaging and other disposable materials in the first place, then reusing and recycling the remainder where possible.

So, remember the 3 R's: **Reduce, Reuse and Recycle.**

What can you do to help?

You could try having a waste free lunch! Lunchtime can mean a lot of waste: plastic and paper bags, crisp packets, drinks cartons, yoghurt pots, napkins, etc.

Challenge your friends and teachers to have waste free lunches. If you work together you could reduce lunchtime waste to almost nothing. Set your class waste reduction targets and write a questionnaire to see how much disposable packaging and single serving products your friends, parents and teachers buy. If you use an electronic questionnaire, you could save even more paper!



Recycling plastics

Plastic is a man-made **polymer**, which is a really long molecule built from many small molecular units repeated and joined together. It can take up to 700 years for plastic to decompose and disappear from our landfill sites or dumps. This makes the recycling of plastics particularly important. Six different types of plastic have been designed to be recyclable. If you live in an area where plastics are recycled, you'll need to be aware of the numbered plastic recycling logos. We illustrate these below, together with what the different plastics can be used to make:



Polyethylene terephthalate (PET) *for water and pop bottles*



High-density polyethylene (HDPE) *for milk bottles*



Polyvinyl chloride (PVC) *for medical tubes, blood bags*



Low-density polyethylene (LDPE) *for plastic bags*



Polypropylene (PP) *for ketchup bottles, yoghurt pots*



Polystyrene (PS) *for meat and fish trays*

How many examples of each type of plastic can you find? Write down the kinds of things made from each. Can you find any other plastic abbreviations?

Other types of waste – waste electronic equipment

Over 20 million computers became obsolete in 1998 and only 13% were recycled! Electronic circuit boards, batteries and the tube inside your TV set contain hazardous materials such as lead, mercury and chromium. If not disposed of properly, these toxins can leach out of landfill sites and be released into the environment. In just one year, over 50,000 tonnes of valuable materials were recovered from disposed electronics for recycling and reuse – including steel, glass, plastic and precious metals like gold.

So, next time you ask for a new computer, stereo or mobile phone, where will your old one go? Can it be recycled? Do you really need a new one?

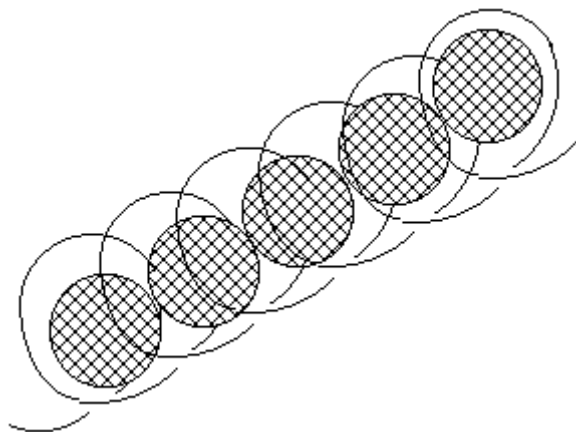
Digesting the facts about starch

In contrast to plastic, starch is a natural polymer increasingly used to make environmentally-friendly packaging materials. Starch consists of spiral chains of sugars and these chains can break down into small sugar molecules that dissolve in water. This natural breakdown, or **biodegradation**, is accelerated by substances known as **enzymes** (we say it is *enzyme catalysed*). The same digestion process begins as soon as we put starchy food into our mouths, as saliva contains just the right enzyme, amylase. You can find out more about enzymes in our activity DIY DNA.

We can see this process in action using some iodine tincture. This is available from chemists' shops as an antiseptic for treating minor wounds. You only need a very small amount and it is cheap. **Caution: the solution (in alcohol) is flammable. It will also stain skin and other surfaces and it will sting on cuts or broken skin. Use it carefully, with a dropper to add one drop at a time.**

You can prepare a starch solution to experiment with by boiling some rice and retaining the water (**please ensure you have adult supervision when handling boiling water**). Allow it to cool and keep the top half of the liquid by pouring it off into a container. You can discard the lower portion, which contains the larger starch particles.

Place about 10-20 ml (1-2 dessertspoons) of your starch solution in a small glass and carefully add one drop of iodine tincture. What do you see? You should observe the instant formation of a deep blue colour with deep blue bits of starch floating around. This colour is caused by iodine molecules trapped in the spiral amylose molecules of starch, like our diagram below:



Now you can repeat the experiment, but this time add some saliva first by rolling a mouthful of water round your mouth for a while and adding this to your starch solution. Leave it for a while before adding a drop of iodine solution. What do you see this time? You can experiment by varying the amount of saliva used and the time elapsed before testing with iodine. The saliva contains the amylase enzyme – what is it doing to the starch?

Further investigations

You can test other foods (such as breads, rice grains and fruit) for starch by placing them on a saucer and adding a drop of iodine solution. See if saliva reduces any blue/black staining.

Twelve principles of green chemistry

Green chemistry is the pursuit of more environmentally friendly ways of making chemicals. Here are twelve principles which underlie green chemistry (don't worry, we don't expect you to understand all the jargon, they just illustrate what kind of issues green chemists have to think about!):

Prevention

It is better to prevent waste than to clean it up after it is formed.

Atom economy

Synthetic methods should be designed to maximise the incorporation of all materials used into the final product.

Reducing hazards

Wherever practicable, synthetic methods should use and generate substances of minimum toxicity to humans and environment.

Safer chemicals

Chemical products should be designed to preserve efficacy of function while reducing toxicity.

Safer solvents/auxiliaries

Use of auxiliary substances (solvents, separation agents, etc.) should be limited, and be innocuous when used.

Energy efficiency

Energy requirements should be minimised. Synthetic methods should use ambient pressure and temperatures.

Renewable feedstocks

A raw material or feedstock should be renewable rather than depleting, wherever technically and economically practical.

Use fewer steps

Unnecessary derivatisation (blocking group, protection/deprotection, temporary modification of physical/chemical processes) should be avoided wherever possible.

Catalysis

Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.

Pollution prevention

Analytical methods are needed to allow for process monitoring and control prior to the formation of hazardous substances.

Biodegradability

Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.

Accident prevention

Substances and the form of a substance used in the chemical process should be chosen so as to minimise the potential of chemical accidents, including releases, explosions and fires.

Adapted from Anastas, P. T.; Warner, J. C. 'Green Chemistry: Theory and Practice', Oxford University Press: New York, 1998.

Recycling wordsearch

There are lots of kinds of solid wastes that can be recycled. Do you already recycle some of the items on this list? Try to find them in the grid below.

<i>Iron</i>	<i>Brass</i>	<i>Zinc</i>	<i>Lead</i>	<i>Office paper</i>
<i>Wood</i>	<i>Tin cans</i>	<i>Tyres</i>	<i>Cars</i>	<i>Aluminium can</i>
<i>Plastic</i>	<i>Concrete</i>	<i>Steel</i>	<i>Leaves</i>	<i>Motor oil</i>
<i>Copper</i>	<i>Gold</i>	<i>Metal</i>	<i>Rags</i>	<i>Newspaper</i>
<i>Paper</i>	<i>Jars</i>	<i>Glass</i>		

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D E A G N C O N C R E T E P T
R M O T O R O I L N F O S Y C
U W F Z K L U O T A X S R H O
V L F C J Z D G W C I E T D R
R T I N C A N S L M S I A A R
E S C O P P E R N U M B C E U
P H E G X O Z O W I E V L L G
A D P A P E R S Q N T A T L A
P L A S T I C S W I A J L Z T
S T P I Z U H T O M L M A W E
W B E C U B D E O U S I H R D
E G R A G S T E D L N D P Z S
N F D A W A O L E A V E S P Q
C E O X S U H A J C H C A R S
E C T A S S A L G F T Z I N C

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This activity was used by us for Science Week 2003, the BBC Tomorrow's World Roadshow in July 2002 and at the BAYSday 'Hands-on Science' event held at Imperial College, London in March 2003.



Science on the Shelves Project

‘DIY DNA’ Activity Sheet

In this activity, you can:

- learn how to extract DNA from a kiwi fruit in your own kitchen and
- use a pineapple to discover about enzymes.

Please follow any **safety instructions highlighted like this in red.**

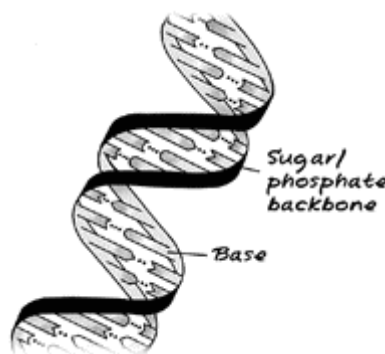
Extracting DNA from a kiwi fruit



DNA is the polymer of life, storing the information that makes all living things what they are, from us humans to the humble kiwi fruit. It is found in the cells of every living thing, including those kiwi fruit! (If you’re curious about the term **polymer**, you can find out more about it in our Go Green activity.)

The DNA molecule has a fascinating double-helix structure, with two backbone strands joined by pairs of molecular groups called **bases**.

Have a look at the drawing to the right, which illustrates the basic structure of DNA. It is the order of the bases that store the information necessary to describe living things – you can think of the bases as a bit like the lines of a computer program.



It’s difficult to imagine what a single DNA molecule looks like as it’s so small. However, we can help you see a bunch of real DNA with an experiment carried out in your kitchen to extract the DNA from a kiwi fruit.

Materials – what you'll need

- A bottle of methylated spirits,
- some salt,
- cheap washing-up liquid (concentrated doesn't work as well),
- kiwi fruit (preferably ripe),
- some ice,
- some hot water,
- a sharp knife and chopping board,
- kitchen scales,
- a measuring jug,
- two bowls (one small, one large),
- a saucepan,
- a fork,
- a sieve and
- a glass.



Method – what you need to do

1. Put the methylated spirits into a large bowl of ice so it cools straight away (see Figure 1). **Do not put methylated spirits into a fridge or freezer as a spark could ignite fumes.**
2. Mix of 25g salt and 80g of washing-up liquid with 900ml water in a small bowl. Stir carefully to avoid too much froth (Figures 2a and 2b).



Figure 1



Figure 2a



Figure 2b

3. Peel a kiwi fruit and chop finely. Using a fork, mash the kiwi fruit into a paste (*Figure 3*).
4. Put the kiwi paste into a small bowl and add 100ml of the salt-detergent mix from step 2. Sit this in a saucepan of hot (not boiling) water for 15 minutes (*Figures 4a and b*).



Figure 3



Figure 4a



Figure 4b

5. Pour the green paste through the sieve into a glass (*Figure 5*).
6. Drizzle the ice cold methylated spirits down the side of the glass so it forms a purple layer on top of the green kiwi paste. You will need an equal amount of methylated spirits and kiwi paste (*Figure 6*).
7. You should see a white string-like layer form in the glass between the green and the purple layers. This is your extracted kiwi fruit DNA – congratulations! (*Figure 7*).



Figure 5



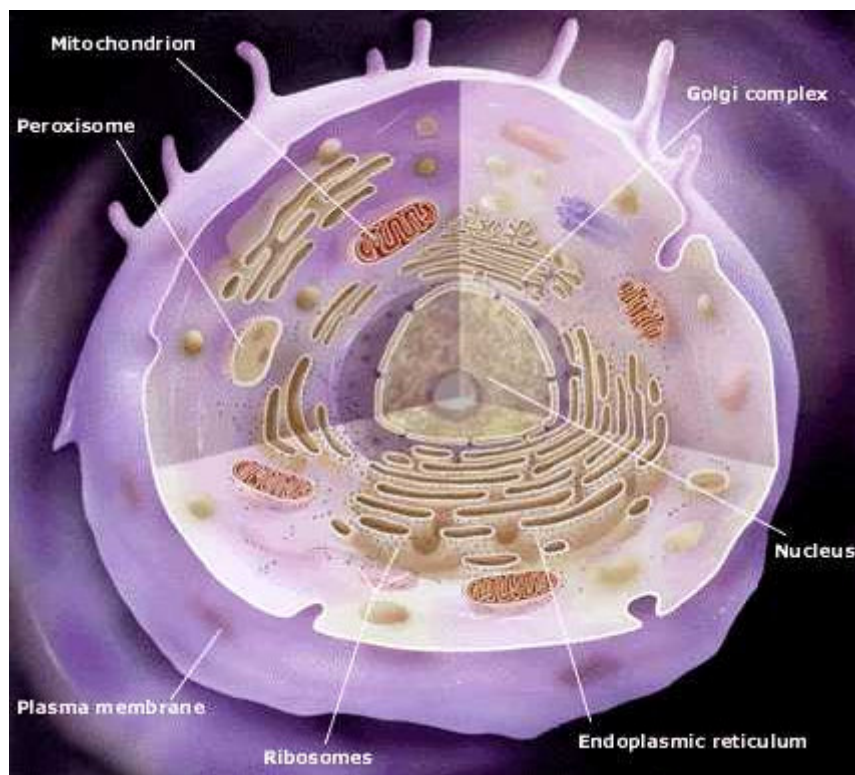
Figure 6



Figure 7

How does the DNA extraction work? – the science bit

DNA is found within the chromosomes inside the nucleus of the cells that make up every living thing, including your kiwi fruit. To extract this DNA, we have to separate it from all the other cell parts. The picture below illustrates a cross-section through a cell – the DNA we want to extract can be found in the nucleus, at the very heart of the cell.



By chopping and mashing up the kiwi fruit, then leaving it in the salt and detergent mix, we break open the cell walls, called **membranes**. This lets all the cell contents out, including the DNA. But the DNA is still surrounded by polymers called **proteins**. Luckily, kiwi fruit contain an **enzyme** called proteinase – this attacks and breaks up the proteins, freeing the DNA.

The green kiwi paste now contains your freed DNA, but also has all the other cell stuff that you have released. Passing it through a sieve removes most of these unwanted bits. Then, when you pour the methylated spirits on top, the DNA turns into a solid, because it can't stay dissolved in the methylated spirits.

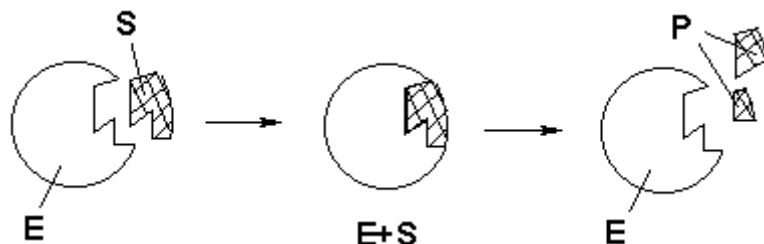
You might get bubbles in between the purple and green layers. This is because of the different temperatures of the two layers. It makes the air dissolved in the green layer come out as bubbles!

This experiment relies on an enzyme in the kiwi fruit to unlock the DNA. Enzymes are powerful polymer machines that help make things work faster (you can find out more about enzymes below). Apples and oranges don't have enough of these enzymes to work with this experiment, as the DNA won't be set free. However, an onion does!

How do enzymes work?

Enzymes catalyse (speed up) reactions in living things – they oil the wheels of the machinery of life! Each enzyme operates on a specific substance, called its **substrate**. They fit together like a lock and key, allowing only the correct combination.

Have a look at our diagram below. It shows an enzyme (E) catalysing the breakdown of another substance (S, the substrate) into two different products (P). Catalysis occurs because substance S fits precisely into surface of the enzyme E, so this reaction and no others are speeded up.



Here are two simple experiments to show enzymes in action. You'll need:

- a ripe fresh pineapple,
- a tin of pineapple,
- fruit jelly cubes (or another gelatin product),
- 3 small bowls and a knife.

First experiment – fresh pineapple

1. Prepare the jelly according to the instructions on the packet.
2. Leave it to cool and set in a small bowl.
3. Once the jelly has set, cut a piece off the fresh pineapple and place it on top.
4. Observe and record results.

Second experiment – fresh and tinned pineapple

1. Prepare enough jelly for two bowls, following the packet instructions.
2. Leave to set in two small bowls, one with a piece of tinned pineapple in, the other with pieces of the fresh pineapple in.
3. Observe and record results.

What's going on? – the science bit

There are many types of proteins, all made up of units called **amino acids**. Altogether there are 20 amino acids. They are linked in chains of different lengths and orders to make all the different proteins. Gelatin is a protein, which makes the jelly set; enzymes are a special type of protein too and can be found in the pineapple.

In the first experiment, when you place a chunk of fresh pineapple on top of the jelly, enzymes from the pineapple catalyse the digestion of the gelatin in the jelly. Therefore, the chunk of pineapple starts to sink into the jelly as its enzymes help breakdown the gelatin.

In the second experiment, the jelly containing the tinned pineapple should set much more effectively than the jelly with the fresh pineapple. Enzymes from the fresh pineapple are breaking down the gelatin that the jelly needs to set properly. With the tinned pineapple, this doesn't seem to be a problem. Can you think why?

It turns out that enzyme molecules are sensitive to heat – their unique structures are destroyed by heat and they are no longer able to function as catalysts. Most tinned foods are heat-treated during pasteurisation to prolong their shelf life. In contrast to the fresh pineapple, the enzymes in the tinned pineapple have been denatured (destroyed) by heat and can't assist in the digestion of the gelatin protein.

This activity was used by us at the BBC Tomorrow's World Roadshow in July 2002.



Science on the Shelves Project

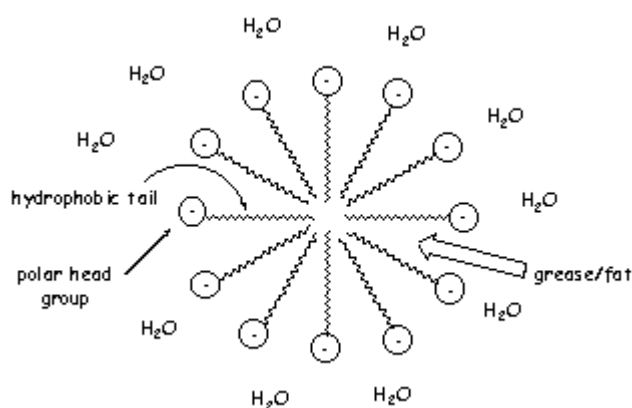
‘Supermolecules’ Activity Sheet

In this activity, you can:

- discover how supermolecules get your washing up clean,
- do an experiment to build your own supermolecules and
- use supermolecules to make your own blue sky.

Supermolecules and your washing up

Washing up liquid contains detergent molecules. These molecules have a very specific structure – with a polar head group and a long hydrophobic (water-hating) tail. When you dissolve the detergent in water, it assembles automatically to form a **supermolecule**. The hydrophobic tails interact with one another and want to hide from the polar water molecules. The charged head group, in contrast, wants to interact with the polar water molecules. These interactions cause the detergent molecules to assemble into a spherical supermolecule called a **micelle**, like the one in our diagram:



It is these giant micelles that make the washing up liquid work. Any oily, greasy substances on your plate will want to go inside the micelle. Inside the micelle, the greasy substances can avoid the polar water molecules and interact instead with the long hydrophobic tails of the detergent. Using these supermolecules, therefore, your plates will end up sparkling clean, as the micelles encapsulate all the greasy waste. But don't forget, detergents are not just for washing up and you can find a more frivolous use for them in our Soapy Science activity.

You don't only wash up with supermolecules – sometimes you even eat them! Many foods contain both oil and water and somehow they have to mix in order to give a smooth tasty product. In order to achieve this, molecules called **emulsifiers** are added. These emulsifier molecules form supermolecules, rather like the micelles in washing up liquid, allowing the oil and water to mix. Salad cream is a good example of a product containing emulsifiers. Egg yolk can be used as a natural emulsifier.

Further investigations

How many different foods can you find in your kitchen that contain emulsifiers (look on the lists of ingredients)?

What do the different foods have in common?

Build your own supermolecules

To make your own supermolecules, you'll need:

- a small clear plastic bottle (a small soft drink bottle is ideal),
- a measuring jug,
- some cooking oil (olive oil or sesame oil works well),
- washing up liquid.

To build your supermolecules:

1. Remove any labels from the bottle so you can see inside it clearly.
2. Using a measuring jug, measure 250 ml of tap water into the bottle.
3. Then add enough oil to form a thin layer on top of the water. This will be about 20 ml of oil (or 2 dessertspoonfuls). It is best if the oil is coloured, such as olive oil or sesame oil.
4. Shake the bottle and leave to settle. You should clearly see the oil floating in a layer on top of the water.
5. Add a small amount of washing up liquid to the bottle. Shake well. What do you observe? There will be lots of bubbles and the oil should begin to mix with the water, giving a cloudy solution. This is because the oil is going inside the micelle supermolecules you've made, which mix with the water.

Further investigations

How much washing up liquid do you need to get reasonable mixing of the oil and water?

Do different brands of washing up liquid have different efficiencies?

Blue sky research!*

It's an age-old question, but just why is the sky blue? To investigate, why not create some blue sky in your kitchen? You'll need:

- a clear plastic or glass container, ideally square/rectangular & straight sided,
- a powerful torch to play the part of the sun,
- a small quantity of milk or powdered milk.

To create your blue sky:

1. Fill the container with tap water, then add a very small quantity of milk powder or a drop of liquid milk.
2. Look at the container from the side and gradually add a bit more milk until you notice a bluish tinge reminiscent of the sky. Remember, you can always add a bit more milk but you can't take any out! Stir well.
3. Shine the torch through and look at the container from the side, at right angles to the direction of the light beam. Then look directly into the light beam from the opposite side of the container. It might help to close the curtains in the room before you do this.
4. In each case, what do you notice? You should see a blue sky looking at the container from the side; looking directly through the water at the light source causes it to appear yellow or red depending upon the amount of milk used.
5. Try adding a little bit more milk/powder and see what effect it has.

How does this work? – the science bit

Milk is an emulsion of fat droplets in water, stabilised by protein molecules acting as emulsifiers and forming supermolecules. These droplets scatter light; in the same way, molecules in the atmosphere scatter light giving the appearance of a blue sky.

White light from the sun, or the torch, contains all the colours of the rainbow. Certain colours are scattered more than others – you can see this as you view the container from different angles. Which colour is scattered the most and which the least?

Can you make a container sunset? – further investigations

It's even possible to set up and watch your very own sunset in a tank! A few extra chemicals are required so why not read about Tyndall's experiment? You can find out more about it here: <http://intro.chem.okstate.edu/ChemSource/Solutions/demo2.html>.

**By the way, blue sky research is speculative work that isn't expected to produce immediate benefits, but may one day lead to a scientific breakthrough. That day could be many decades away!*

This activity was used by us at the BBC Tomorrow's World Roadshow in July 2002.



Science on the Shelves Project

'It's a Gas!' Activity Sheet

In this activity, you can:

- learn how to make your own fizzy drinks,
- learn how to make sherbet,
- discover the easy way to inflate a balloon and
- blow your top by making a rocket.

Please follow any **safety instructions highlighted like this in red.**

How to make fizzy drinks

It's easy to make your own special Fizz Powder which, when added to drinks, makes them fizzy. You will need:

- citric acid crystals,
- bicarbonate of soda,
- icing sugar.

Note that **the citric acid crystals must be food grade**, which you can find in the baking section of your supermarket, or get from chemists and home-brew suppliers. To make some fizz powder, here's what you need to do:

1. Add 6 teaspoons of citric acid crystals to 3 tablespoons of bicarbonate of soda in a bowl.
2. Crush the mixture with a spoon to form a fine powder.
3. Now add 2 tablespoons of icing sugar, mix thoroughly and put into a dry jar labelled *FIZZ POWDER*.
4. To use the powder, put 2 teaspoons into a glass and fill it up with the still drink of your choice.

How does the fizz powder work? – the science bit

The citric acid reacts with the carbonate in bicarbonate of soda to form carbon dioxide gas. These bubbles of carbon dioxide are what make your drink fizzy. You can find out more about carbonates in our Eggsperiments activity.

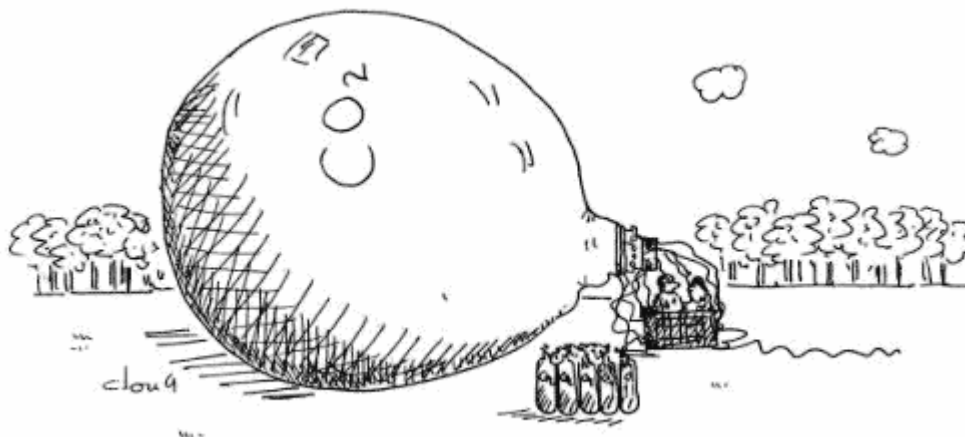
Why not test the acidity of different drinks? – further investigations

Add a teaspoon of bicarbonate of soda to half a glass of a drink (for example, grapefruit juice) and half a glass of a different drink (for example, orange squash). Whichever drink fizzes most is the more acidic!

How to make sherbet

Using the same ingredients as the fizz powder you can also make sherbet! Simply follow steps 1 and 2 above for the fizz powder, but then add 4 tablespoons of icing sugar instead. When you put the sherbet on your tongue, the citric acid crystals dissolve and react with the bicarbonate of soda. This produces bubbles of carbon dioxide gas, which cause the fizzy feeling on your tongue.

The easy way to inflate a balloon – without blowing!



***"I know it's cheap, plentiful and non-flammable
but there's a drawback with this gas..."***

Yes, you can inflate a balloon without blowing into it yourself! You will need:

- vinegar,
- baking soda,
- a bottle,
- a balloon.

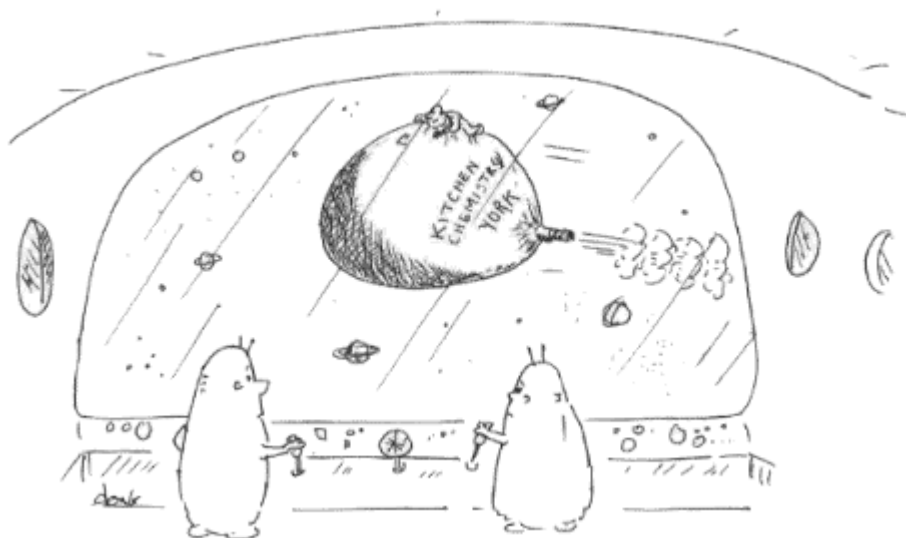
Here's what to do:

1. Pour about 20 ml of vinegar into the bottle.
2. Put 2 teaspoons of baking soda into the balloon.
3. Attach the balloon around the neck of the bottle, taking care not to let any baking soda fall into the bottle (you may need some sticky tape to secure the balloon).
4. Once the balloon is securely fastened to the bottle, lift the balloon so that the baking soda is tipped into the bottle. Sit back and watch the balloon inflate!

What makes the balloon inflate? – the science bit

When you tip the baking soda out of the balloon into the bottle, it mixes with the vinegar and a chemical reaction produces carbon dioxide gas. As the gas can't escape, the balloon inflates.

Use a rocket to blow your top!



"Not another Science on the Shelves rocket!"

WARNING! This experiment produces a high-speed projectile! **Follow all highlighted safety instructions and wear safety goggles.**

Rockets and explosives function by generating huge volumes of gas in a short time. You can create your own rocket using citric acid and baking soda. You can also use vinegar and baking soda, but citric acid is preferable because things don't take off until you add water and it's not so smelly! **Doing this outside is also preferable as it makes a mess.** You will need:

- a small plastic photo film canister (translucent ones are best),
- baking soda,
- citric acid crystals, or vinegar.

Here's what to do:

1. Mix about a 1/4 teaspoon of baking soda and citric acid crystals in the film canister.
2. Add a few drops of water, quickly snap the lid into place and **stand clear**. If you use vinegar, put the baking soda in first, then snap on the lid as soon as you've put in a few drops of vinegar.
3. The lid should blow off dramatically after a short time, but be patient!

Never allow anyone to look over the top once the canister is 'charged'. If it fails to go off (as it does sometimes if there's a small leak around the lid) or seems to have failed, open it very carefully keeping your face well away.

Why is the top blown off? – the science bit

When the citric acid crystals and baking soda dissolve in the water they react with one another producing carbon dioxide gas. The pressure builds up inside the film container until the point at which it can force the lid off. The lid then blows off and the pressure is released.

Can you control the explosion? – further investigations

You can time how long it takes for the lid to come off and experiment with quantities, mixing and so forth, until you can get the lid to come off after exactly one minute, say.

This activity was used by us for Science Week 2003, the BAYSday 'Hands-on Science' event held at Imperial College, London in March 2003 and the British Association Festival of Science at Salford in September 2003.



Science on the Shelves Project

‘Let’s Get Physical’ Activity Sheet

In this activity, you can:

- discover how to grow your own crystals and
- learn how to make your own silly putty.

Please follow any **safety instructions highlighted like this in red.**

Crystal growing

Growing crystals is great fun and it’s easy too, though you’ll need some patience. The easiest way to start is to grow Epsom salts in a dish. Dissolve a tablespoon of Epsom salts in five tablespoons of water and stir until all the salt has dissolved. Pour the solution into a dark coloured dish and leave it on one side to evaporate, preferably in the sunshine. As the water evaporates you’ll see a lovely crop of needle-like crystals form.

With a little more care you can grow a large single crystal. Start by dissolving as much table salt as you can in a beaker of warm water. When no more salt will dissolve, pour a little of the water into a saucer and leave it in the sun to evaporate. Salt crystals will form. Notice that they look quite different to the crystals of Epsom salt that you grew in the same way.

Now, select a nice large crystal from this crop and tie a thread to it (tricky!). Suspend this threaded crystal in the beaker of salty water by tying the thread to a pencil. If you leave it to stand undisturbed for a few weeks a large salt crystal will form.

See who can grow the biggest crystal, but don’t get as carried away as our friend in the cartoon! You can try this with table salt or with other crystalline materials too, such as sugar.



Can you find any other crystals? – further investigations (i)

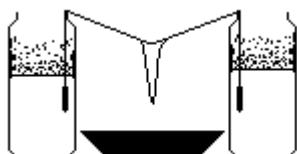
Look out for crystals all around you. At home, you can often find some good examples in bottles of wine. These are crystals of tartaric acid formed as the wine ages in the bottle. You will probably also be familiar with honey, which can be a thick, clear liquid, or set and opaque. In set honey, the sugars have crystallised out. Out of doors, you will see that certain kinds of rocks, such as granite, consist of millions of tiny crystalline particles.

Can you grow a crystal icicle? – further investigations (ii)

Now that you are really good at growing crystals, why not have a go at growing a crystal icicle? You will need:

- bicarbonate of soda (baking soda),
- a piece of wool,
- paper clips,
- two glass jars,
- a saucer.

The diagram below illustrates what you have to build:



First, make a saturated solution of bicarbonate of soda and fill both jars with it (you can make this saturated solution by dissolving as much bicarbonate of soda as you possibly can in some water). Get a piece of wool and tie paper clips to either end. Suspend each end in the jars, with a saucer under the thread and leave to rest. As the solution soaks up and along the wool, it drips out and leaves a crystal icicle behind.

How to make silly putty



"... but this silly putty looked just like a cake!"

To make silly putty, you will need:

- PVA glue (15ml, or 3 teaspoons),
- talcum powder (5 ml, or 1 teaspoon),
- food colouring (a few drops),
- water (25 ml, or 5 teaspoons),
- Borax solution (5 ml, or 1 teaspoon),
- a glass tumbler,
- a plastic bag,
- some paper towels.

You can buy PVA (polyvinyl alcohol) glue from craft shops, and you may already have some at home. Talc is optional, but it does seem to improve the elasticity of the silly putty. Borax powder is readily available from pharmacies and hardware shops, **but you must be careful with it, as it is harmful when swallowed.** Here's what you do to make your silly putty:

1. Measure the glue into the tumbler (it doesn't have to be too exact). About 15ml (three teaspoonfuls) is enough. The more glue you add the more silly putty you'll get.
2. Next add about 25ml (5 teaspoons) of water to the tumbler and sprinkle in one teaspoon of talc. Stir thoroughly with the spoon to mix the contents of the tumbler until you have a smooth grey paste. Break up any clumps of talc that form at the sides.
3. Now add drops of the food colouring until you get the colour you want, but be careful not to add too much.
4. You now have a tumbler full of colourful, watery glue. It's time for the magic ingredient: borax. Make a borax solution by stirring a heaped teaspoon of borax into a glass of water. Add a teaspoonful of this borax solution to your tumbler of silly putty and stir. Once the borax is mixed in thoroughly, take the spoon out and pull the putty off it.
5. Work the solid material with your hands for a few minutes. At first it will be quite slimy, but soon it will become smooth and dry. Have the paper towels ready so you can wipe any colour and goo off your hands. **You should lay out your plastic bag to protect the work surface.** And there you have it - silly putty. Now your only problem is putting the infernal stuff down!

Wrapped up in a plastic bag or in an airtight container, silly putty will keep for as long as you want it. If the putty dries out then adding a small amount of water will take you back to the messy stage again. If the silly putty gets onto fabric or carpet it can be removed with a little vinegar followed by warm soapy water.

If you want to try your hand at making play dough as well as silly putty, we have some recipes for play dough in our Fun with Flour activity.

This activity was used by us for Science Week 2003, the BAYSday 'Hands-on Science' event held at Imperial College, London in March 2003 and the British Association Festival of Science at Salford in September 2003.



Science on the Shelves Project

‘Red Hot, Cool Chemistry’ Activity Sheet

In this activity, you can:

- make your own ice cream using chemistry,
- perform an eggciting experiment,
- make your own thermometer,
- find out whether hot water freezes faster than cold and
- find out how hot is what.

Please follow any **safety instructions highlighted like this in red.**

Using chemistry to make chocolate ice cream



"What a salesman!"

This must be one of the best uses of science in the kitchen! You will need:

- 1 tablespoon of cream,
- 2 tablespoons of milk,
- 1 tablespoon of chocolate powder,
- ice cubes,
- salt,
- two bowls: one large, one small.

Place the cream, milk and chocolate powder into the smaller bowl. Put a bed of ice cubes into the larger bowl and sprinkle with salt. Press the smaller bowl into the salted ice. Add another layer or two of ice and salt around the smaller bowl, then cover with a tea towel and leave it to sit. Stir the ice cream mixture every few minutes.

What's going on? – the science bit

Well, we all know that water freezes at 0 °C, but when we add an impurity to the water, such as salt, we can lower the temperature at which ice melts. Why not experiment by measuring the temperature of the ice/water whilst making your ice cream? This same principle is used when we put salt on the roads in winter to make them safer to drive on.

Can you make water unfreezable? – further investigations

So, we know that adding salt stops water from freezing at the usual 0°C. We can investigate this by adding some salt to water and putting it in the freezer. Using a thermometer, find how cold the water will get before it freezes. Does adding more salt allow it to go even colder without freezing? (you may need to turn the freezer down, but make sure you ask permission!) How low can you go?

Eggciting chemistry

Everybody knows that when you boil an egg it goes hard, but do you know why? At what temperature does it happen?

Here's a simple experiment to find out at what temperature the egg changes. All you'll need is a kitchen and a thermometer. Separate the white of an egg and add it to a small pan of water on the stove. **Heat gently**, using the thermometer to find out at what temperature the egg white goes opaque (clue: it's about 60°C). How accurately can you measure this?

Egg white is made of **proteins**: big, complicated molecules built into a very precise shape, like a dinosaur skeleton. Heating the egg causes the protein to shake and eventually collapse. The temperature at which the egg goes hard is the temperature at which these proteins collapse.

How to make your own thermometer

How do we know how hot something is? An easy way is just to test with your hand; but what happens when it gets too hot or cold to touch safely? For a scientist, being able to measure temperature accurately is very important. Using some simple science we can make a thermometer! You will need:

- a straw,
- some modelling clay or Blu Tack,
- a small clear plastic bottle with lid,
- some food colouring.

Here's what you need to do:

1. Pour cold water into the bottle until its about 1/4 full. Add a few drops of food colouring.
2. Make a hole near the top of the bottle and insert a straw so that it dips in the water; make a tight seal around the straw using Blu Tack or modelling clay.
3. Blow into the straw and make bubbles until the water rises halfway up.
4. With a marker pen, mark the level of the water in the straw; this is room temperature.

Experiment putting your thermometer in hot and cold places! The thermometer works because as the temperature rises, the air inside the bottle expands and pushes the water up the straw. At cooler temperatures, the air in the bottle contracts and the water drops.

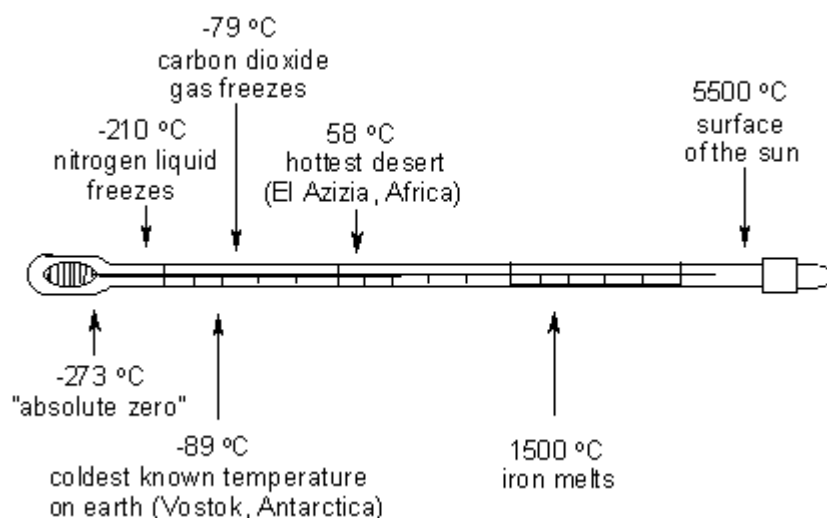
Mpemba and how hot and cold water freeze

Mpemba was a young African boy who worked in Tanzania making ice cream. He was making the ice he needed one day when he noticed that hot water freezes faster than cold water! None of the expert scientists would believe him but luckily one grown up, his science teacher, did. Together they managed to convince the experts that Mpemba was right. Not only that, but the experts named it the 'Mpemba Effect' after him. To this day, no-one really knows why it happens.

You can try this in your kitchen – just take some hot water from the kettle and some cold water and put them both in the freezer. Keep checking them. Which one freezes first? Does the size and shape of the container have an effect? Does the type of container used affect which freezes first?

Temperature talk – how hot is what?

Have a look at our thermometer below. How much do you think the temperature varies where you live over a day, or between summer and winter, compared to these extremes?



This activity was used by us for Science Week 2003 and at the BAYSday 'Hands-on Science' event held at Imperial College, London in March 2003.



Science on the Shelves Project

'Soapy Science' Activity Sheet

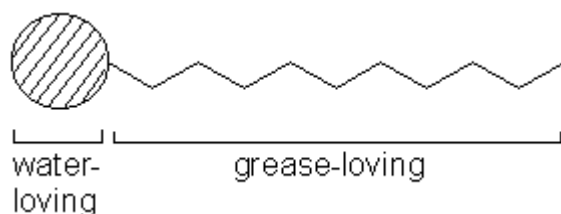
In this activity, you can:

- find out how detergents work,
- carry out four bubble-making experiments,
- explore surface tension and
- measure it by making your own button balance.

How do detergents work?



Soaps and detergents are made from long molecules that contain a head and tail. These molecules are called **surfactants**; the diagram below represents a surfactant molecule.

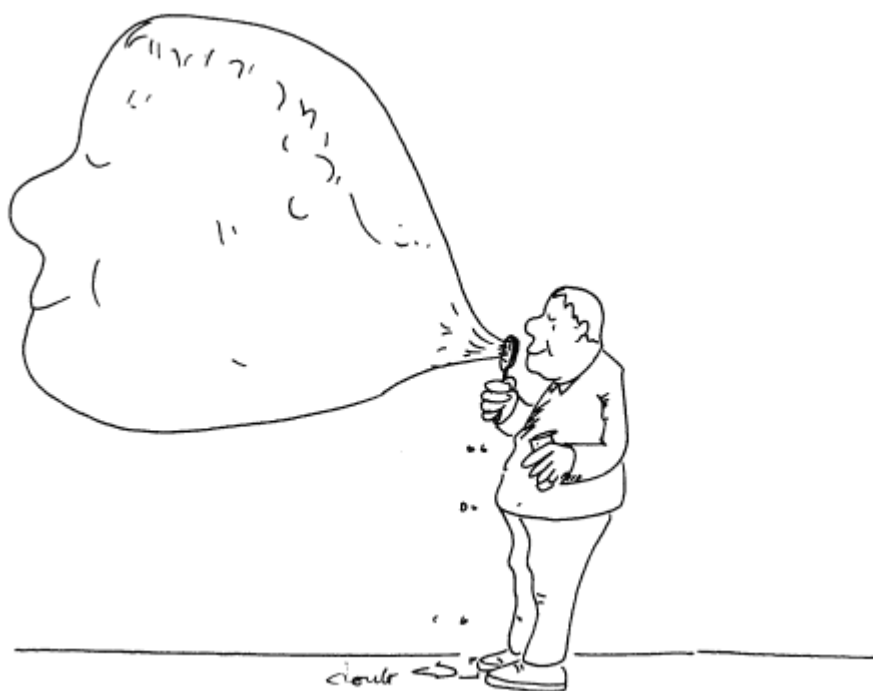


The head of the molecule is attracted to water (hydrophilic) and the tail is attracted to grease and dirt (hydrophobic). When the detergent molecules meet grease on clothes, the tails are drawn into the grease but the heads still sit in the water.

The attractive forces between the head groups and the water are so strong that the grease is lifted away from the surface. The blob of grease is now completely surrounded by detergent molecules and is broken into smaller pieces which are washed away by the water. You can find out more about how detergents work in our Supermolecules activity.

The detergent molecules also help to make the washing process more effective by reducing the **surface tension** of the water. Surface tension is the force which helps a blob of water on a surface hold its shape and not spread out. The surfactant molecules of the detergent break apart these forces and make water behave, well, wetter!

Making bubbles



Bubbles and soap films are made of a thin layer of water, sandwiched between two layers of soap molecules. You can make giant bubbles by mixing these ingredients together:

- 1 litre of water (distilled is preferable, but tap water will do),
- 15 ml good quality washing-up liquid (we used Fairy),
- 10 ml glycerol/glycerine (from your supermarket's cake-baking section).

Once you've made your bubble solution, you can try our four experiments!

Experiment 1

Use your hands to make a hoop-shape. Dip them in the bubble solution and blow gently but firmly. Using this method you should be able to blow bubbles up to about 60 cm in diameter!

Experiment 2

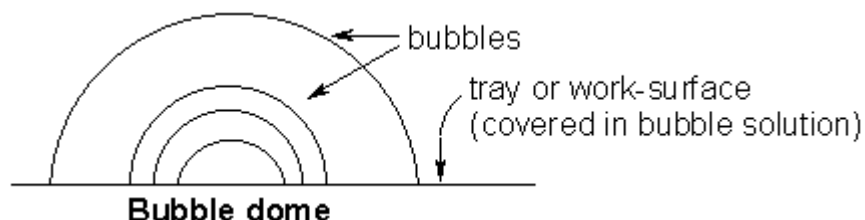
Dryness not sharpness breaks bubbles. Blow a large bubble then try putting your fingers inside it. If your hand is wet you can touch and even place your hand inside the bubble without bursting it! A soap bubble is only 1/500,000th of a centimetre thick as it starts to pop!

Experiment 3

Make a large hoop of string about 1 metre in diameter and tie 4 small loops at the corners to make handles. Dip this into the soap solution and with a friend pull the handles apart to form a giant soap film. Trying shaking one end and watch the wave travel along the film.

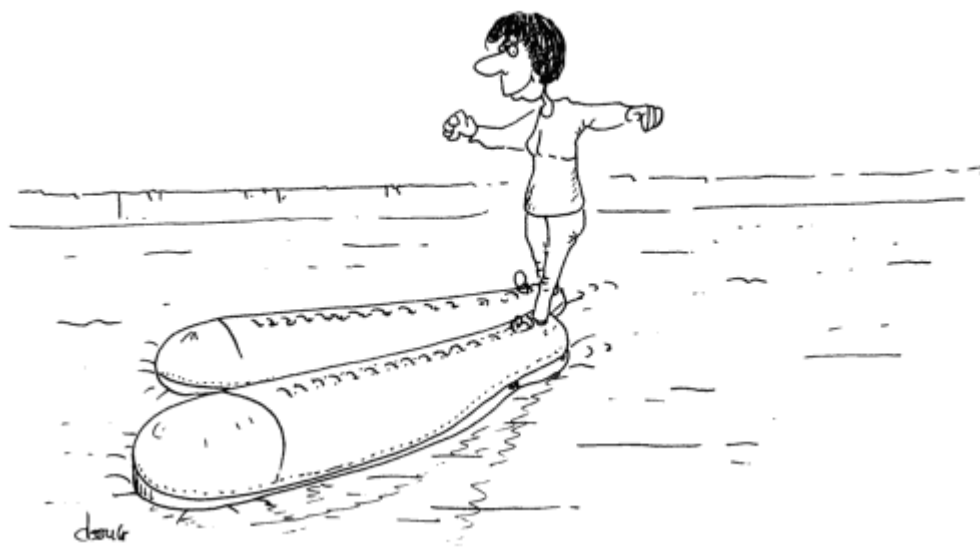
Experiment 4

Now try and make a bubble dome, like our diagram below.



Wet a tray or the kitchen work-surface with your bubble solution. Using a straw, blow a large bubble. Push the straw through the original bubble and blow a smaller one inside. See how many smaller bubbles you can make!

Exploring surface tension



"The introduction of the Dr. Marten size 338 finally allowed Annie to walk on water"

Water has many unusual properties, one of which is the phenomenon of surface tension. As we said earlier, surface tension is the force that prevents a blob of water on a surface from spreading out. Surface tension allows pond skaters and other insects to walk across water and also allows a pin to float.

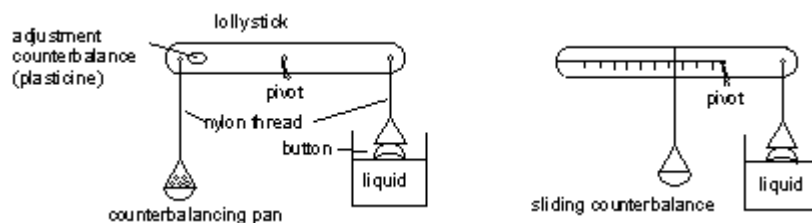
You can demonstrate this yourself by taking a bowl of water and floating a pin on the surface. Carefully add just one drop of washing-up liquid and see what happens to the pin. It should sink immediately because the detergent molecules break apart the forces holding the water together. The pin is no longer supported and so sinks to the bottom!

Measuring surface tension – the Button Balance

You can measure surface tension yourself by making your own button balance, like the one used by the famous nineteenth century home experimentalist, Agnes Pockels. You will need:

- a lollystick,
- some nylon thread,
- a button,
- some plasticine,
- some graph paper,
- a piece of card,
- a container to hold the liquid to be tested.

Here's how to build your button balance:



You can set up the balance in one of two ways, as shown in the diagram above. You'll soon find out which one works best for you. The lollystick is used for the lever and the nylon thread has the advantage of not soaking up water and influencing the balance. The piece of card can be suspended from the lollystick with the nylon thread to act as a counterbalance pan. Small squares of graph paper can be used as weights – you can weigh a large number of whole graph paper sheets and work out from this what each small square weighs. To use your balance:

1. Balance the lever before you start, for example by sticking a piece of plasticine on the lollystick.
2. Raise your container of liquid up carefully so that the button (rim downwards) settles gently onto the surface. You should notice the lever tip towards the liquid.
3. Depending on which design you have used, you either add small weights to the counterbalance pan or slide the counterbalance along gradually until the point where the button comes off the liquid surface. You can try to put the button back on the liquid surface just to check that it is the weight that has pulled the button off rather than the act of dropping the weight into the counterbalance pan (or sliding the counterbalance).

4. For each measurement, you can record the number of squares of paper required to remove the button from the liquid surface (or, convert this to an actual weight), or record the position of the sliding counterbalance along the graduated lever. Try repeating your experiment to see how close together the measurements are. How accurate do you think your balance is?

With your button balance, try measuring the surface tension of a range of liquids and comparing them. For example: cold water, salt water, warm water and soapy water. You can also try changing the size of the button used or the material it is made out of.

This activity was used by us for Science Week 2003 and at the BAYSday 'Hands-on Science' event held at Imperial College, London in March 2003.



Science on the Shelves Project

‘The Acid Test’ Activity Sheet

In this activity, you can:

- find out about acids and bases,
- discover how to make a cabbage water pH indicator and
- learn how to write secret messages.

Please follow any **safety instructions highlighted like this in red.**

Acids and bases

What do lemons and vinegar have in common? They both taste sour on your tongue. This is because they are **acids** and acids taste sour. **Bases** are the opposite of acids; they normally taste bitter and feel soapy. Lots of washing powders are bases (**WARNING: Do not taste these!**). Another word for a base is an alkali and we say that bases are alkaline compounds.

Some properties of acids and bases are:

- acids have a sour taste,
- acids are corrosive,
- acids lose their acidity when they are combined with bases and
- bases feel soapy.

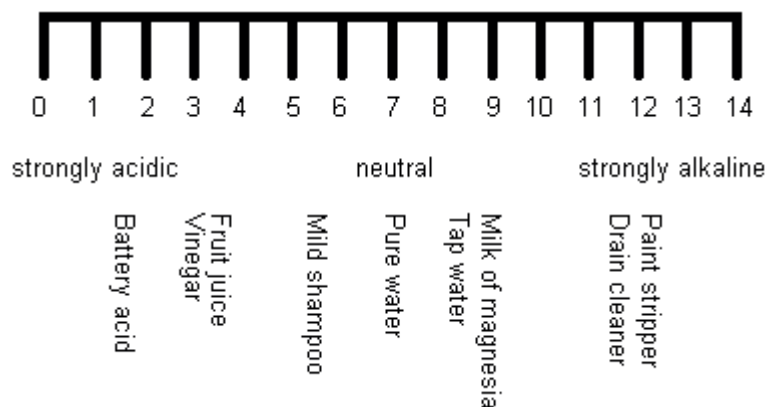
Acids can sound really scary and some of them undoubtedly are, requiring very careful handling. **As a precaution you should be wary of anything called an acid.** However, there are a great many acids which are not only harmless to us but are vital to our survival.



Did you know that Vitamin C is another name for a form of ascorbic acid? You'll find ascorbic acid together with another naturally occurring acid – citric acid – in orange and lemon juice. These are harmless partly because they are what's known as weak acids.

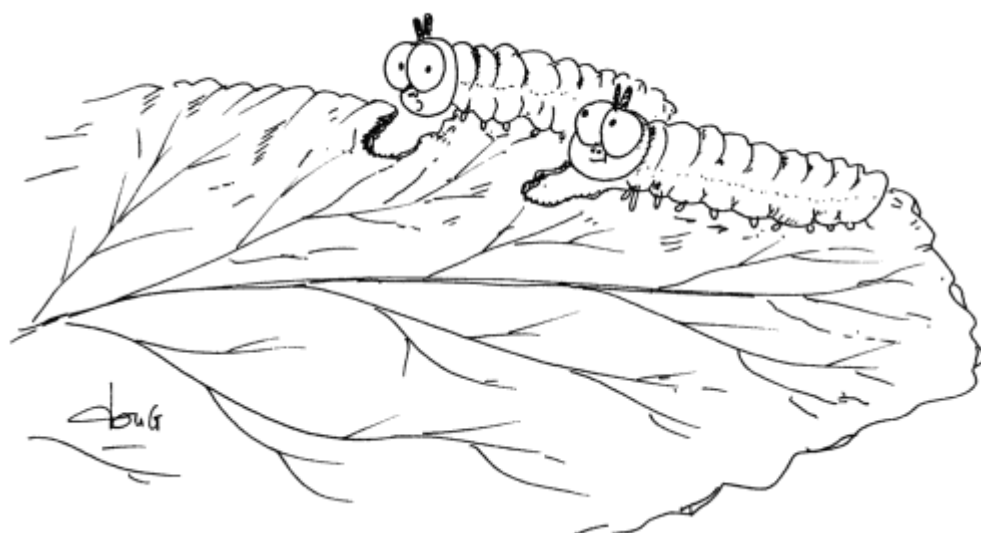
Acids react with bases and weak acids only really react with very strong bases. The problem with strong acids and strong bases is that they are so strong that they can always persuade even the weakest of bases or acids to react with them. There usually is something around to fill that role since all substances lie somewhere on a scale between being strong acids and being strong bases. Most natural substances lie in the middle zone where they're neither particularly acidic or basic.

Scientists use something called the **pH scale** to measure how acidic or basic something is. The pH scale measures acidity in the same way that a millimetre scale measures length, for example. A low pH indicates an acidic compound (an acid), whilst a high pH indicates a basic compound (a base). Here is an illustration of the pH scale from 0 (strongly acidic) to 14 (strongly alkaline) showing how acidic, or basic, some everyday things are:



Things that are neither acidic nor basic are **neutral** and come in the middle of the pH scale – for example, pure water in the illustration above. Knowing whether something is acidic or basic can be very useful. For example, wasp stings are alkaline but bee stings are acidic. So if you get stung you need to put bicarbonate of soda on a bee sting and vinegar on a wasp sting. Hair conditioner is slightly alkaline as shampoo tends to be slightly acidic, so any traces of shampoo can be neutralised by the conditioner. What does this tell you about all-in-one shampoo/conditioners?

How to make an indicator solution







"It's really weird, if you eat a lemon after a red cabbage, you completely change colour"

Special substances called **indicators** are used to determine whether things are acidic or basic by changing colour. You can make your own indicator from a red cabbage and find out which things in your kitchen are acidic and basic. To make your indicator solution, you need to:

1. Cut the red cabbage up, put it into a saucepan and cover with boiling water. **Please make sure you are supervised by an adult when handling boiling water.**
2. Stir it around and then leave it to soak for 15 minutes.
3. Using a sieve, separate the liquid from the cabbage pieces.
4. Keep the liquid in an old drinks bottle and label it clearly as *INDICATOR*.

To use your indicator solution to test things (the acid test!):

1. Pour some of the indicator solution into several jars and label them.
2. Write *CONTROL* on one of the jar labels. A control is a copy of an experiment in which you do nothing. It is used to show that results are due to the test and not to your equipment, allowing you to do a fair experiment. This jar will be your control, so you won't be adding anything to it – it's there so you can compare it to the others.
3. To the other jars of indicator solution, add a few drops, or bits, of the things you want to test. For example: lemon juice, cola, vinegar, a boiled sweet, washing up liquid, detergents, bicarbonate of soda, shampoo and conditioner.
4. Observe any colour changes in the jars, compared with the control. You can use this cabbage indicator pH scale to determine the acidity:

pH	2	4	6	8	10	12
Colour						
	red	purple	violet	blue	blue green	green

Invisible ink

You can even use the power of acid and base chemistry to write secret messages! You can write a message in invisible ink by doing this:

1. Add 1 tablespoon of bicarbonate of soda (baking soda) to a mug of water.
2. Dip a cotton-wool bud into the mixture and use it like a pen to write your message onto a piece of paper. Handy hint: try not to put too much liquid onto the cotton bud!
3. When the paper is completely dry, rub a red grape over the message. Handy hint: using a hair dryer speeds things up.

Can you work out what's going on? Of the bicarbonate of soda and the red grape, which do you think is acidic and which alkaline?

This activity was used by us for Science Week 2003 and at the BAYSday 'Hands-on Science' event held at Imperial College, London in March 2003.