Basic science: understanding experiments

This item contains selected online content. It is for use alongside, not as a replacement for the module website, which is the primary study format and contains activities and resources that cannot be replicated in the printed versions.

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Week 1: Water content of everyday goods

Introduction

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Janet Sumner is your guide through this course. She is a Media Fellow at The Open University with a specialist interest in volcanoes. Janet will appear at the start of each week to tip you off about the coming highlights and challenges, to remind you what you've learned and to help you make the most of these four weeks of scientific discovery.

Over the next four weeks you will carry out a series of hands-on experiments. These experiments are designed to get you to:

- start thinking in a rigorous and scientific way
- recognise the influence of experiment design and variables
- think about how the world around you works.

This course is going to assume that you are new to studying science, so don't worry if you haven't conducted any experiments before.

The experiments start off simply, but by Week 4 you will be isolating and extracting the DNA of a kiwi fruit! This week, you'll be focusing on why water is so important to all living organisms and carrying out two different experiments – baking a potato to destruction and examining the process of osmosis in cucumbers.

To test your knowledge you can try the end-of-week and an end-of-course quizzes.

There are plenty of opportunities to communicate with other learners. There are forum threads for activities in each week. Please join in!

Before you start, The Open University would really appreciate a few minutes of your time to tell us about yourself and your expectations of the course. Your input will help to further improve the online learning experience. If you'd like to help, and if you haven't done so already, please fill in this optional survey.

What you'll need

All of the experiments can be carried out with items you would find in a typical kitchen, but before you start, you should probably make sure you have the following:

Shopping list

- a cucumber
- a kiwi
- methylated spirits (or a bottle of vodka!)
- olive oil
- a potato
- salt
- sugar
- washing-up liquid
- yeast
- distilled water.

Equipment list

- cling film
- oven gloves
- a freezer
- an ice cube tray
- kitchen scales
- a marker pen
- a microwave or oven
- a paper clip
- a printer
- a ruler
- a vegetable peeler
- drinking glasses
- knife.

Advice for younger learners and homeschoolers

We would like to take this opportunity to remind you of the Conditions of use of Open University websites. To enrol on an OpenLearn course and participate in the forums, you must be aged 16 or over. Adults can use their own OpenLearn account to supervise under 16s on the course, posting comments on their behalf, and assisting with the experiments.

Remember, do not share any personal details such as your home address, email or phone number in any comments you post. You can read more in the OpenLearn FAQs.

1.1 Keeping a study journal

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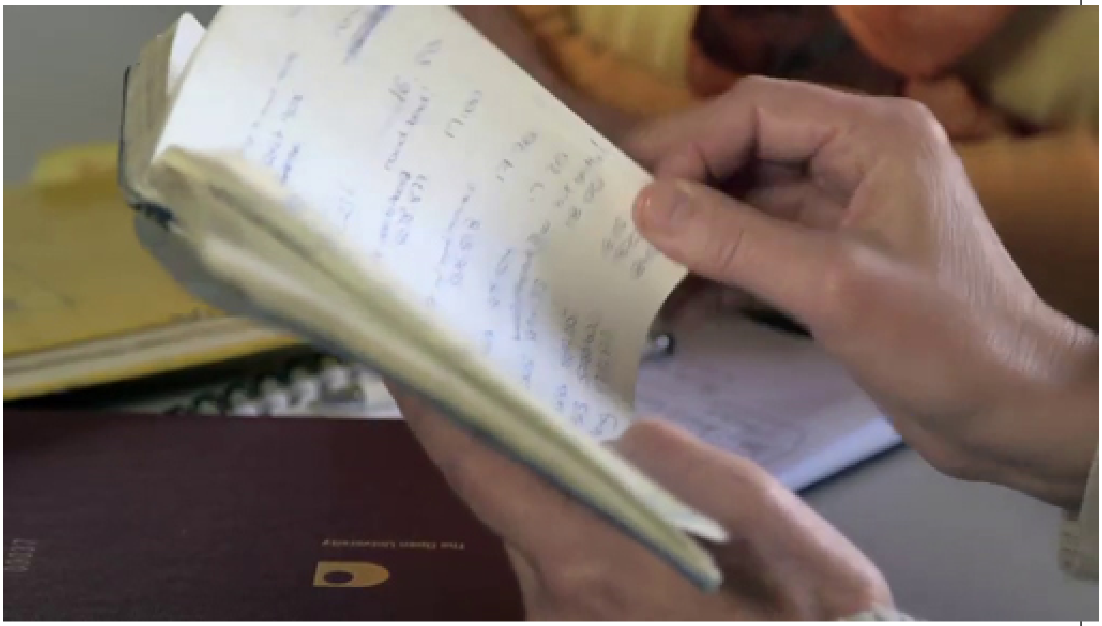

Keeping a study journal, lab notebook or field notebook is a vital skill for any scientist – beginners to the subject often underestimate their importance.

In the video, Janet Sumner and Hazel Rymer, Dean of Science at The Open University, discuss why your notes are so important. Download the activity booklet for this course, it includes everything you'll need to make your personal notes on the experiments. If you would rather use your own journal, that's fine – the type of record that you keep of your experiments is less important than the clarity and detail of your notes.

A good rule of thumb is that your notes should contain enough information that someone else could use them to duplicate your work, or that you could read through them years later and remind yourself of the exact procedures that you followed. It is always far better to have recorded too much information and not need it, than to not record enough and find that a vital piece of information is missing.

1.2 Introducing the experiment

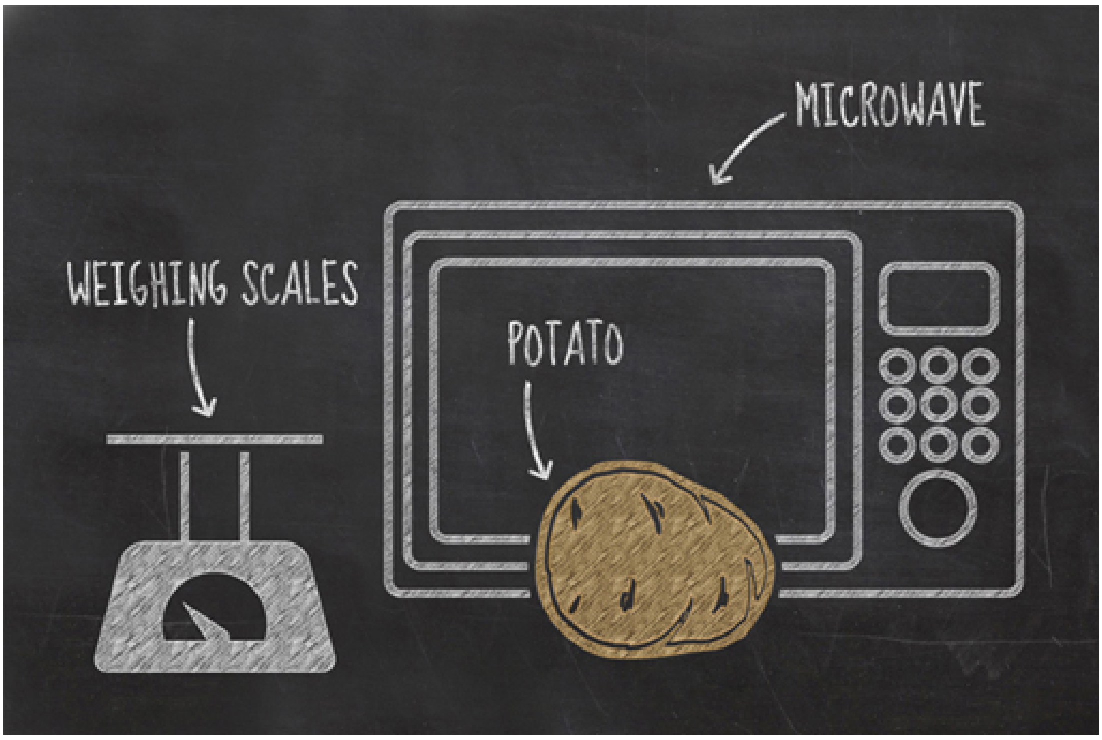

Figure 1

One of the best ways to start thinking more scientifically is by looking at everyday items and experiences in more detail. Your first experiment will be based on an everyday process – cooking.

You will be looking at the relationship between heat and the water content of a potato, measuring the change in water content as heat is transferred to a potato during the cooking process.

If you have ever microwaved a potato before, you will have noticed that steam is expelled during the process. By cooking the potato to destruction you are aiming to drive off all of the water contained within it, enabling you to calculate its water content.

To conduct this experiment, you will need:

- a potato
- oven gloves
- scales (digital scales will give a clearer reading)
- your activity booklet
- a pen
- a ruler
- a microwave or conventional oven.

If you do not have a microwave oven and wish to use a conventional oven, you will need to have longer cooking times with longer intervals between readings.

Although it can reasonably be expected that most people will have similar results, there will be small differences based on the type of oven used, the type of potato, and the length of the cooking. These are the experiment variables; they are the parts of an experiment that can be controlled, changed or measured. Variables, and their importance in experiments, will be discussed throughout the course.

1.3 Drawing graphs

This experiment requires you to plot your results on a graph. Before we move on to the actual experiment, here is a quick refresher on how to plot line graphs.

Graphs are a great way of presenting numerical data visually; they are used to illustrate clearly the relationship between quantities. There are several different types of graph, but for this course you will only be focussing on how to use a line graph.

The x-axis and the y-axis

The axes on a graph are your reference lines; they carry the scale of your graph and help you locate where to plot each piece of data. They also tell you what variables your graph is illustrating a relationship between.

Line graphs are commonly used to show data that change over a period of time. A simple line graph is drawn with two axes: an x-axis that is drawn left to right across the page, and a y-axis that is drawn up the page.

Figure 2

Scientists like consistency and it is standard practice to put the thing you're measuring on the y-axis. So, as the change in weight of a potato is what you will be measuring in this experiment, this will be the data plotted on your y-axis. Because you are measuring the change in the potato's weight over time, the time will be the data illustrated by your x-axis. The graph will therefore show the relationship between cooking time and potato weight.

Once you have drawn the axes of your graph, remember to write alongside them both what they represent and the units they are displayed in, i.e., time (in minutes) and weight (in grams).

Figure 3

Setting the scale of your graph

When drawing your axes, you need to number them appropriately for the experiment you are carrying out, so your y-axis should range from zero to a number just a bit larger than the weight of your potato. Your x-axis should be labelled with the number of minutes of cooking time, probably from zero to about 10 to 15 minutes if using a microwave oven, and zero to maybe 100 minutes if you are using a conventional oven.

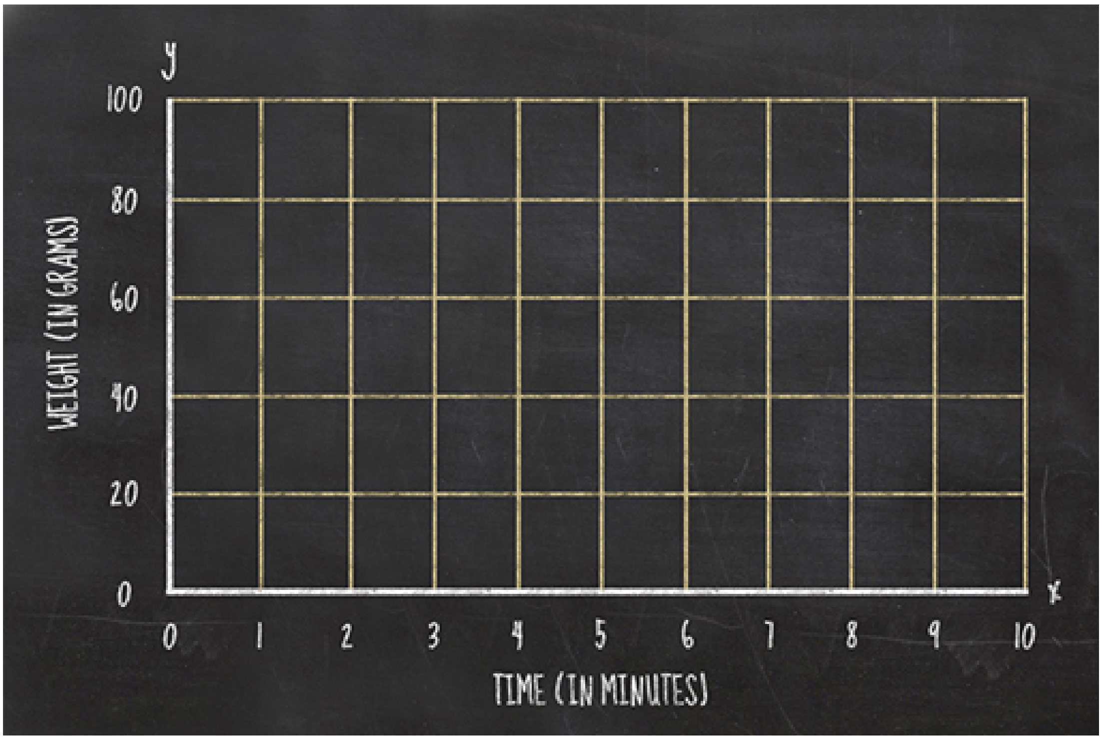

Figure 4

Plotting your data

When you obtain a measurement, you write down the weight and the cooking time. To plot this on a graph, you need to find where those two values intersect. For example, if your potato weighed 90 grams at zero minutes, then you would plot your first data point as a dot at the intersection between those two lines.

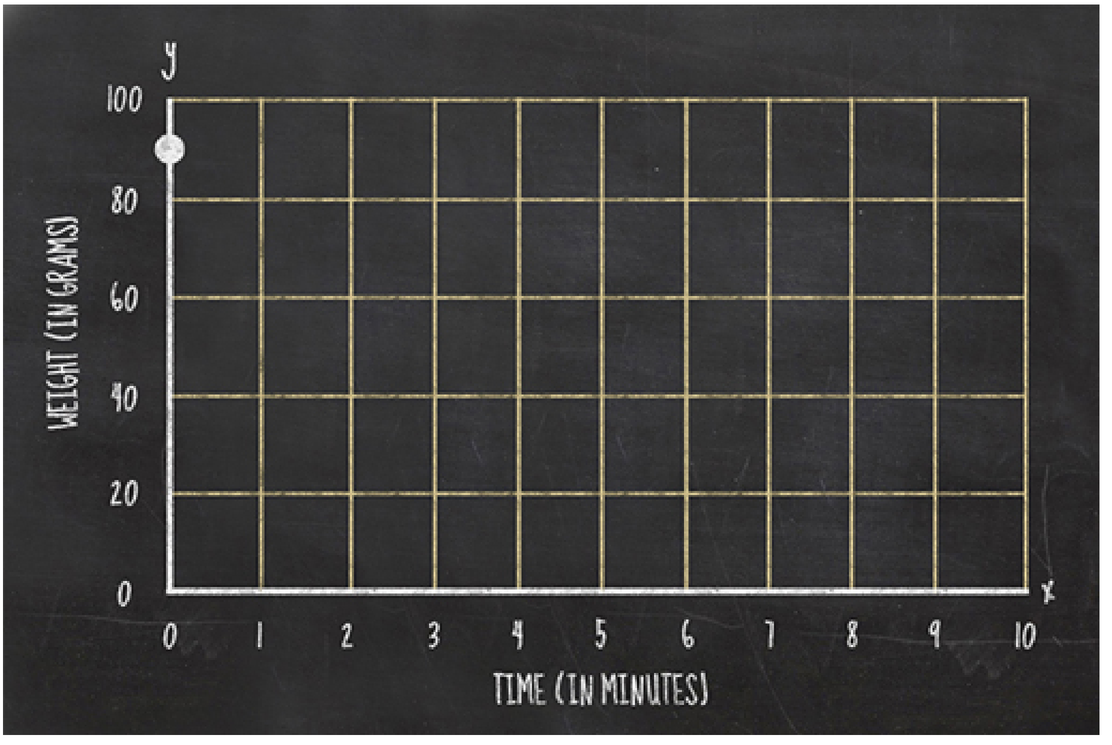

Figure 5

Once you have all your data plotted on a graph you should join the consecutive points with a line.

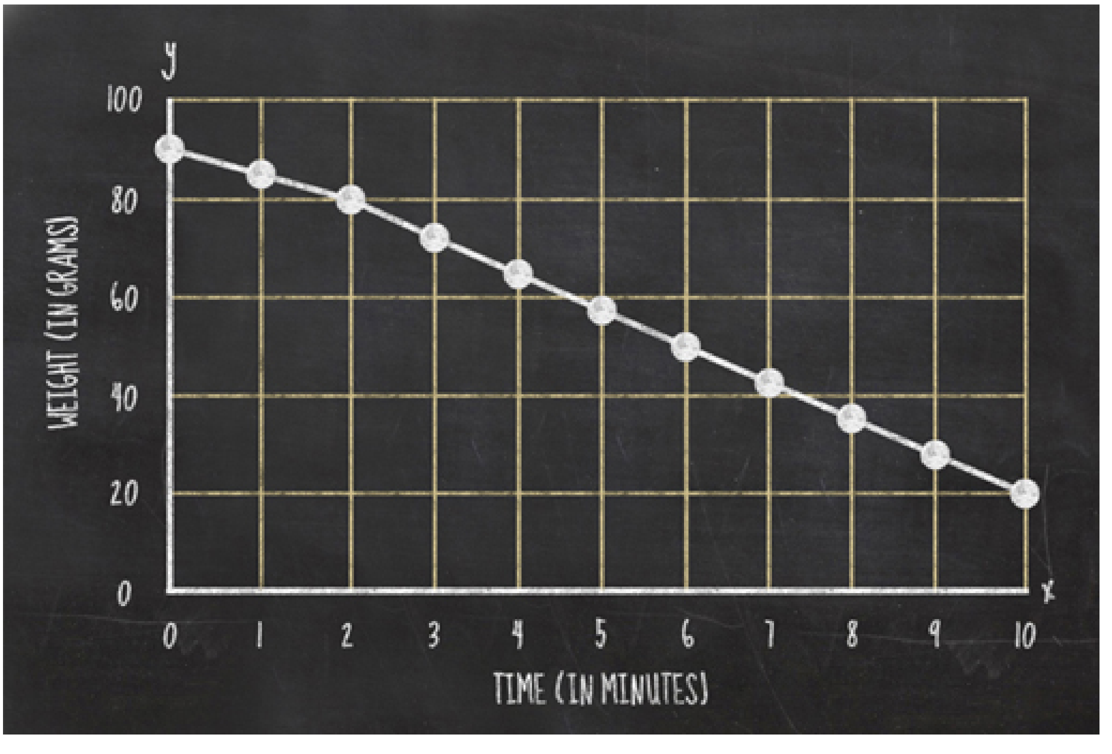

Figure 6

1.4 Experiment 1: Potato experiment

Follow Janet's instructions in the video (or use your activity booklet PDF) to conduct the experiment. Don't forget to prick a few holes in your potato and to use oven gloves when handling your hot potato!

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It is possible to go too far during the cooking process and cause your potato to smoke and potentially catch fire, so **watch** the potato during the experiment, and as soon as you see smoke coming from it, or smell burning, you should bring the experiment to a halt immediately.

This is your first opportunity to document an experiment. Remember the advice in the previous sections and record all your observations and results carefully.

You will have the opportunity to discuss your results in the next section.

1.4.1 What's in your graph?

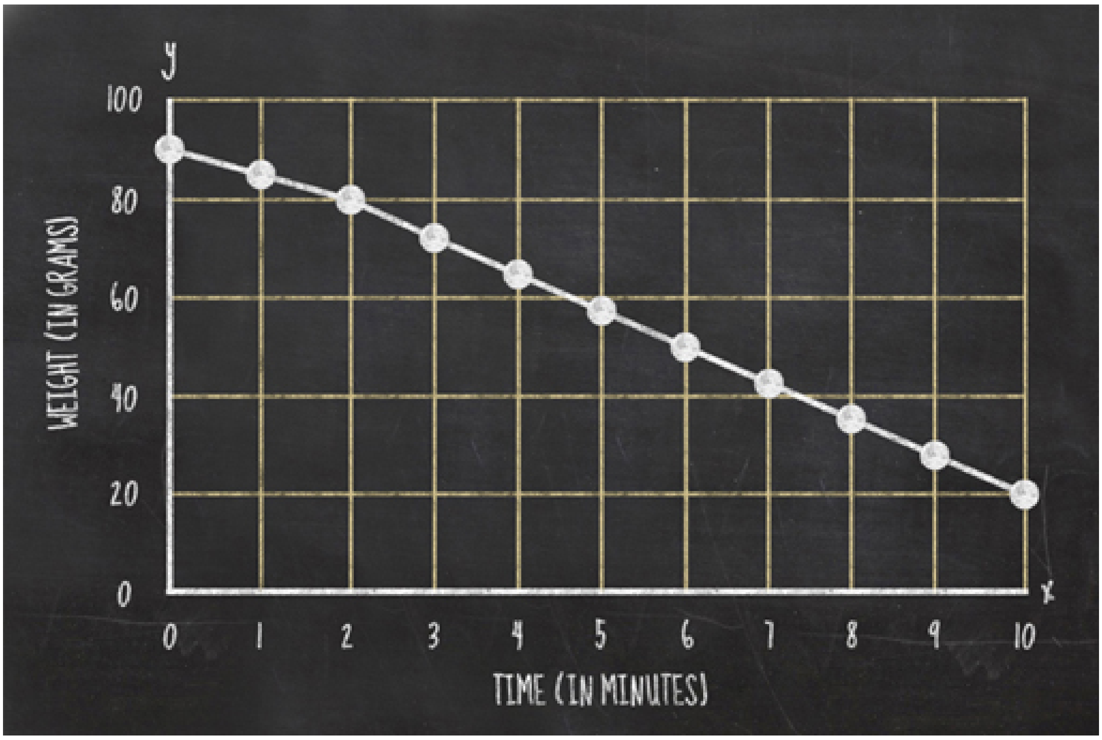

Figure 7

You should now have completed this week's experiment and should be ready to share your findings with your fellow learners. It is very likely that each of your experiments will have produced different results, but you may be able to find general patterns of agreement.

Activity 1.1 Experiment 1

Allow about 30 minutes

What was the water content of your potato? To work this out, you just need to subtract the weight of your potato at the end of your experiment from its starting weight. The difference in the starting and finishing weights is the actual weight of the water that was in your potato.

To compare your results with those of other learners easily, you can express your potato's water content as a percentage. To do this, divide the weight of water in your potato by the potato's starting weight and multiply the answer by 100. It is likely to come out to about 80%.

Post your results in the course forum thread for this activity and compare your findings with those posted by other learners. Discuss why you think any differences came about. Consider the variety of potato you used. Does it make a difference? Do waxy potatoes have a higher water content than floury ones? Maybe drying in a microwave is different from drying in a conventional oven?

It might be useful to provide an image of your graph. You can do this by photographing or scanning your graph and attaching the photograph file with your forum post.

Discussions with other people are crucial parts of the scientific process. It isn't enough to obtain your results and then hide them away; they must be shared and discussed among your peers. Scientists usually do this by having their work critically examined by other scientists to see if it is ready for publication, then publishing their results in scientific journals, where anyone and everyone can examine them. If other people disagree with those results they can carry out research, obtain findings, and publish papers which argue a different case. This is why science produces such a robust body of knowledge. Other people are always trying to spot the flaws in your ideas, and if flaws are there, they are usually found pretty rapidly. A good scientist must always be ready to be corrected.

1.4.2 Why does it matter?

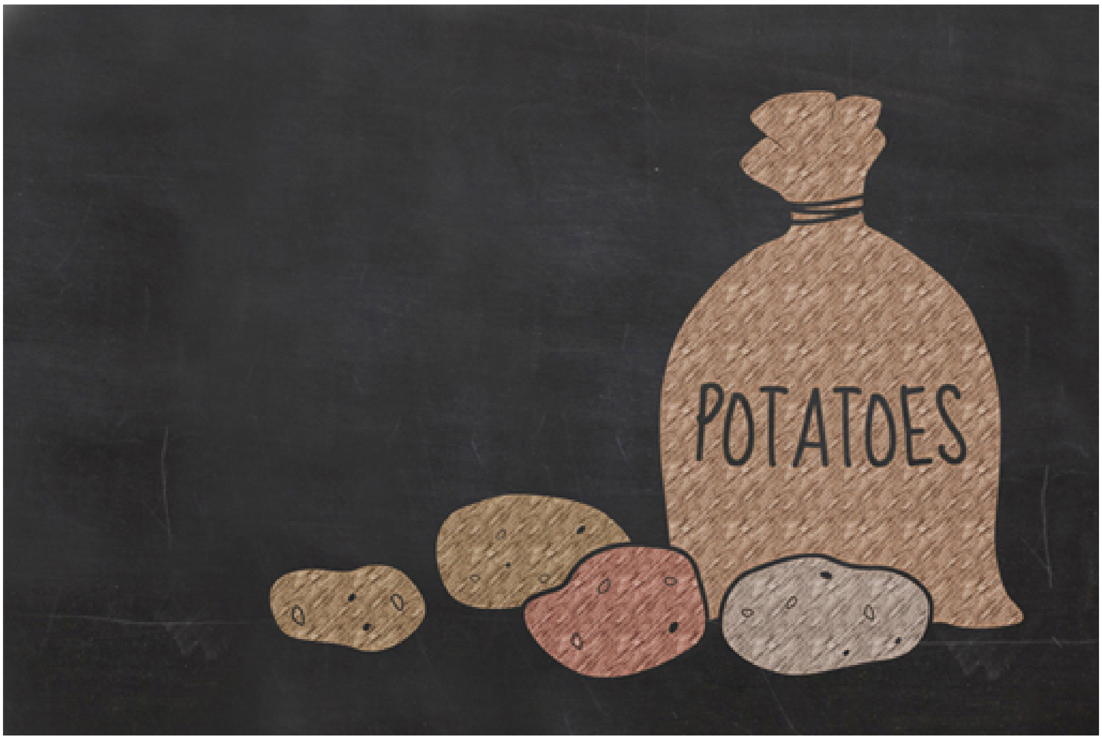

Figure 8

Potatoes originated in South America, and have become a staple food for much of the world's population. About 4000 to 5000 varieties exist, but most of these are only found in the Andes. In the UK, only about 80 varieties are grown, and only a handful of those are sold by the major supermarket chains.

The amount of water required to grow different crops affects which ones are better suited to drier regions, and which ones are better suited to wetter areas. With drought conditions widespread over many parts of the globe, it is better for farmers in those regions to grow crops more suited to drier conditions and crops that require less water to develop are the preferred choice.

This type of farming even has a name: *dryland farming*. It is common in the Great Plains of the USA, the deserts of Mexico and the south-western USA, the steppes of Eurasia, Australia, and parts of South America.

This table shows some of the thirstier crops in production around the world. Do any of these numbers surprise you?

Water-intensive crops	Typical water needs (in litres per kg of crop)
Cotton	7,000 to 29,000
Rice	3,000 to 5,000
Sugar cane	1,500 to 3,000
Soya	2,000
Wheat	900
Potatoes	50

1.5 Experiment 2: Cucumbers and osmosis

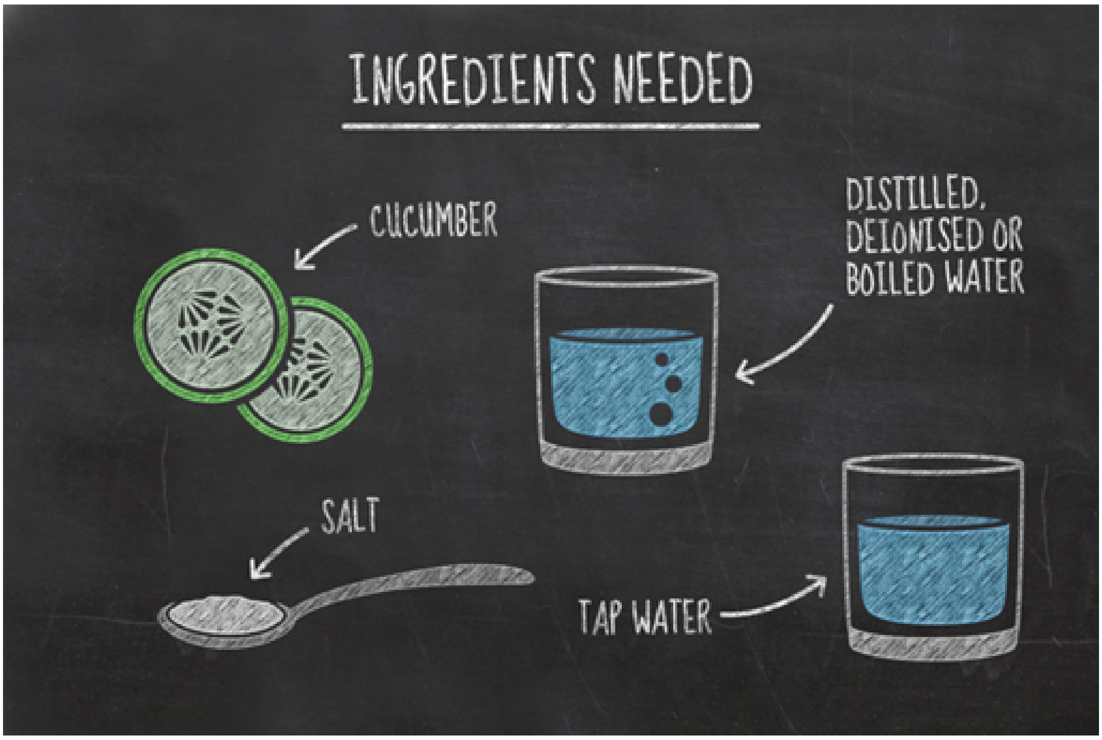

Figure 9

In the previous experiment, you determined the water content of a potato and illustrated the rate at which the water is driven off in your graph. You also developed skills in carrying out an experiment. You're now going to carry out a second experiment looking at the way water gets in and out of cells.

In this experiment, you will be measuring changes in the water content of two slices of cucumber as they are left in two different liquids; distilled water and salty water.

To carry out this experiment, you will need:

- two slices of cucumber
- two glasses
- a knife
- a peeler
- tap water
- distilled, deionised or boiled water
- two tablespoons of salt.

It is best to use distilled water for this experiment, available from most petrol stations and car spares shops. Distilled water is simply water that has had most of its impurities removed by boiling it, then collecting the steam and condensing it in a clean container. An alternative is deionised water, sometimes called demineralised water. This is similar to distilled water, but the manufacturing process does not significantly get rid of organic molecules, viruses or bacteria. If you can't get hold of either of these, you can use boiled water that has been left to cool to room temperature instead.

While it's okay to drink small quantities of distilled and de-ionised water, we don't recommend it. Why do you think the purest form of water might not be good for you? Perhaps you'll be able to see why at the end of the experiment.

Follow Janet's instructions in the video (or use your activity booklet PDF) and remember to keep clear and accurate notes in your journal. Once again, think about the variables that could affect your results.

Video content is not available in this format.

Based on her initial findings, Janet decided to change the parameters of her experiment and leave her cucumber slices overnight. You may find that you have to do the same. If so put the experiment somewhere where no-one can knock it over, and no pets try and drink it.

You'll have the opportunity to discuss your findings in the next section.

1.5.1 Sharing your results

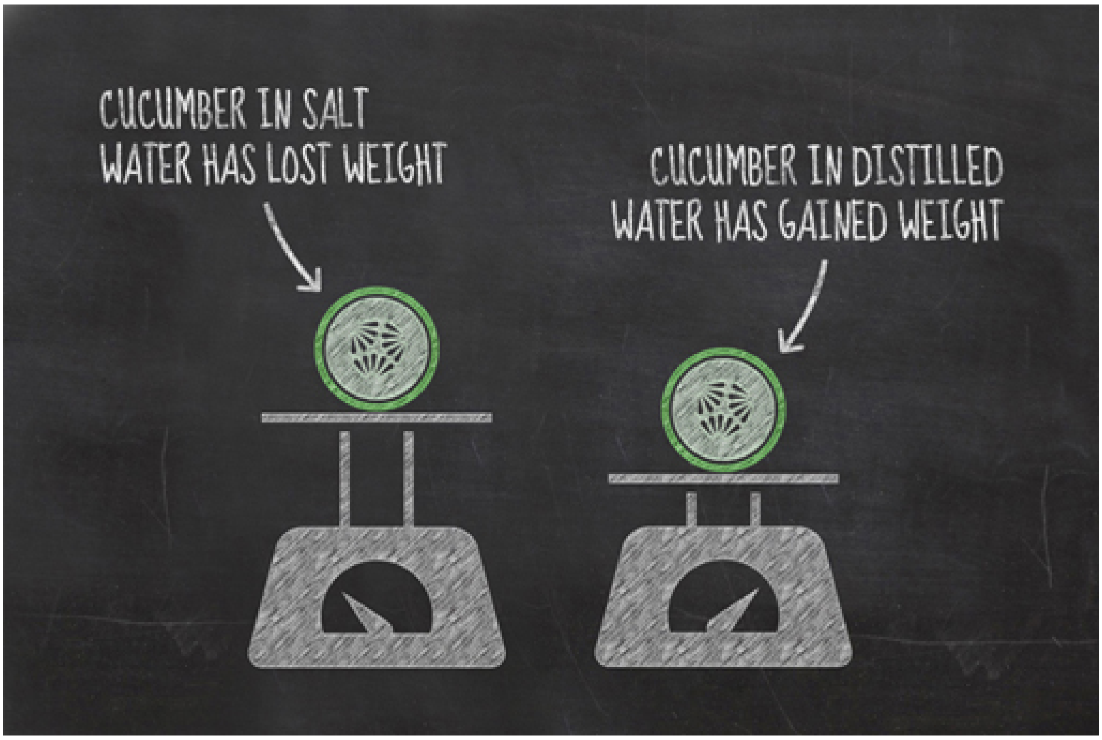

Figure 11

Now that you have completed your second experiment, you will have a new set of results to discuss. Hopefully the results of your experiment were broadly similar to those seen in the video. The cucumber slice in the salt water should have lost weight, while the one in the distilled water should have gained weight.

Activity 1.2 Experiment 2

Allow about 15 minutes

Post your results and observations in the course forum thread for this activity:

- Did the experiment perform as you expected?
- What do you think caused your cucumber slices to change in the way that they did?
- If your cucumber slices haven't behaved in the same way as Janet's did, can you think of a reason why your results might be different?

Photographs can be really useful for comparing your results, so do add an image to your forum post if you can.

Remember, if your results were unusual this does not make them bad – some of the most significant scientific discoveries have stemmed from mistakes or surprises.

1.5.2 Osmosis explained

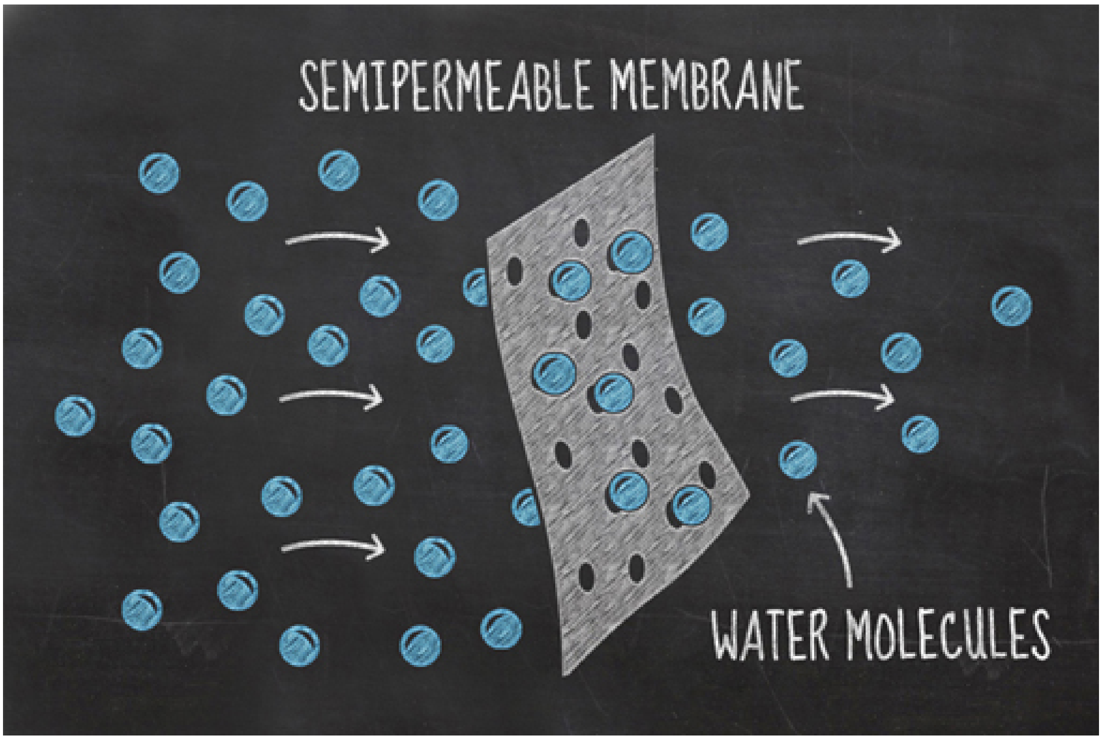

Figure 12

You've seen the results of your experiment and it should be clear that water is somehow moving in and out of your cucumbers – this process is known as osmosis.

Imagine two solutions of different concentrations, divided by a partition which allows small particles through it, but not large particles. This type of boundary is known as a *partially permeable membrane*. In this environment, the process of osmosis will occur spontaneously because the concentrations of water molecules on either side of the partition, or membrane, naturally try and equalise.

In your experiment, the water in the glass and the fluid inside the cucumber's cells are separated by the cucumber's cell walls which are partially permeable membranes. Salt cannot pass through these membranes, but water can. By adding salt to the water, you made its salt concentration higher and therefore lowered the concentration of water in the mixture. This gives the cucumber cells a relatively higher water concentration than that in the glass. The water in the cucumber cells tries to equalise these different concentrations by moving from the cells to the saltwater solution. As a result, the cucumber loses water and becomes a bit squishy. This environment is referred to as *hypertonic*.

In your other glass, containing the distilled water, the opposite effect was seen. Water flowed from the pure water (a higher concentration region) into the cucumber cells (which have a lower concentration of water). In this *hypotonic* environment, the water tries to equalise by moving into the cucumber cells, inflating them, and causing the cells to become firm. This is known as *turgor*, and it is the turgor pressure in plant cells that keeps them rigid. Without it, plants wilt and their cellular functions will begin to decline.

When the concentrations on either side of the membrane are equal, the condition is known as *isotonic*, and water moves randomly from one side of the membrane to the other, but with no pressure gradient to drive it, the rate is the same in both directions.

1.5.3 Why does it matter?

Figure 13

You now know what osmosis is and that it's the process that keeps plants firm but, other than keeping your flowers from wilting, are there any other examples of osmosis in the natural world? Unsurprisingly, the answer is yes, there are many, and here are just a few:

- As well as keeping plants rigid, osmosis is also the way that plants draw water and nutrients into their roots.
- If you've ever stayed in the bath too long and seen your fingers turn a bit 'pruney', it's because your fingertips have absorbed water through osmosis and become bloated, making them wrinkly.
- Ever had salted fish? The fish is covered with salt to preserve it. Osmosis is the process whereby the salt draws water from the fish's cells, drying it out. This, gruesomely, is the same thing that happens when slugs encounter salt.
- If you have soaked raisins overnight in alcohol for a recipe, the liquid soaked into the fruit by osmosis.
- Cholera is rare in developed countries, due to clean water supplies and good healthcare, but it used to be one of the most feared diseases in the world. Cholera damages our intestines in such a way to cause osmosis to happen in an unwanted direction. The cells of the intestine become unable to absorb water and instead it flows from the rest of the body into them, causing diarrhoea, dehydration and often death.
- Industrially, osmosis is used to purify water, at desalination plants where seawater is turned into drinkable water.
- Osmosis is also used in modern medicine. When patients are treated with dialysis to replace lost kidney function, osmosis is the process which is used to filter waste materials and excess water from the blood.

Now, you may remember that Janet mentioned a green energy source in this week's guide video. Well, this relates to the use of osmosis to generate electricity. Where rivers flow into the ocean, freshwater and saltwater naturally meet, resulting in a natural mixing of waters of different salinity. Construction of a power plant at such a site allows freshwater and saltwater to be guided into separate chambers, divided by an artificial membrane. At the membrane, the freshwater is drawn towards the seawater. This flow puts pressure on the side of the seawater and that pressure can be used to drive a turbine, producing electricity that produces no greenhouse gases. The only waste product is brackish water (a mixture of saltwater and freshwater), which can be pumped out to sea.

Power plants that utilise osmosis in this way have been trialled, but only as prototypes, as the technology is still relatively new. The first was in Norway, where it generated up to 4 KW; barely enough to keep a couple of houses supplied with power, and the company shelved their development plans. However the technology can still be developed further, if improvements in the efficiency and cost of the membrane can be achieved.

Those are just a few examples of osmosis in real life, can you find some more? .

1.6 Week 1 quiz

Check what you've learned this week by taking this end-of-week test.

Complete the Week 1 quiz now.

Open the quiz in a new window or tab then come back here when you're done.

1.7 Week 1 summary

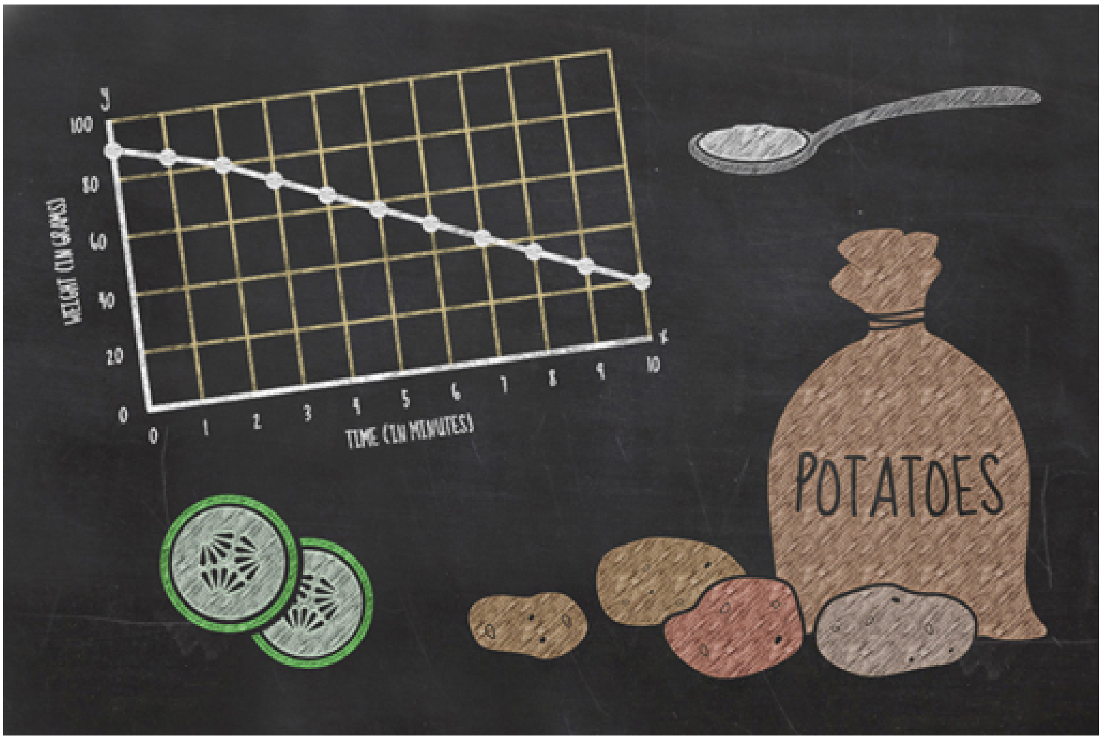

Figure 14

Congratulations, you have completed Week 1 and carried out two different science experiments. You should be starting to get a taste for practical science and sharing data; hopefully you have learned some new things too!

During the week you have covered scientific techniques such as making precise measurements, recording data and observations, plotting graphs, and interpreting results. These are all essential skills for a scientist and you will use them throughout this course.

We hope that you have enjoyed this first week and you should now be ready to tackle Week 2, where you will investigate some properties of different liquids.

To conduct next week's experiment, you will need:

- an ice cube tray
- fresh water
- salt water (approximately 2 tablespoons of salt added to 500 ml of water)
- olive oil
- another liquid of your choice – be creative here, but avoid substances which might be hazardous!
- four glasses
- your activity booklet
- a freezer.

You can now go to Week 2.

Introduction

Video content is not available in this format.

This week, you are going to perform an experiment to investigate how the physical properties of common liquids change when they are frozen.

Like last week, this simple experiment can be performed in your kitchen, but the science behind your results goes far beyond it. In fact, the physical properties of one of the liquids you will freeze are fundamental to life on our planet.

As you work through this week, try and remember the scientific techniques you covered last week, such as making precise measurements, recording data and observations and interpreting any results.

So, clear some space in your freezer and get started!

2.1 Experiment 3: Ice tray experiment

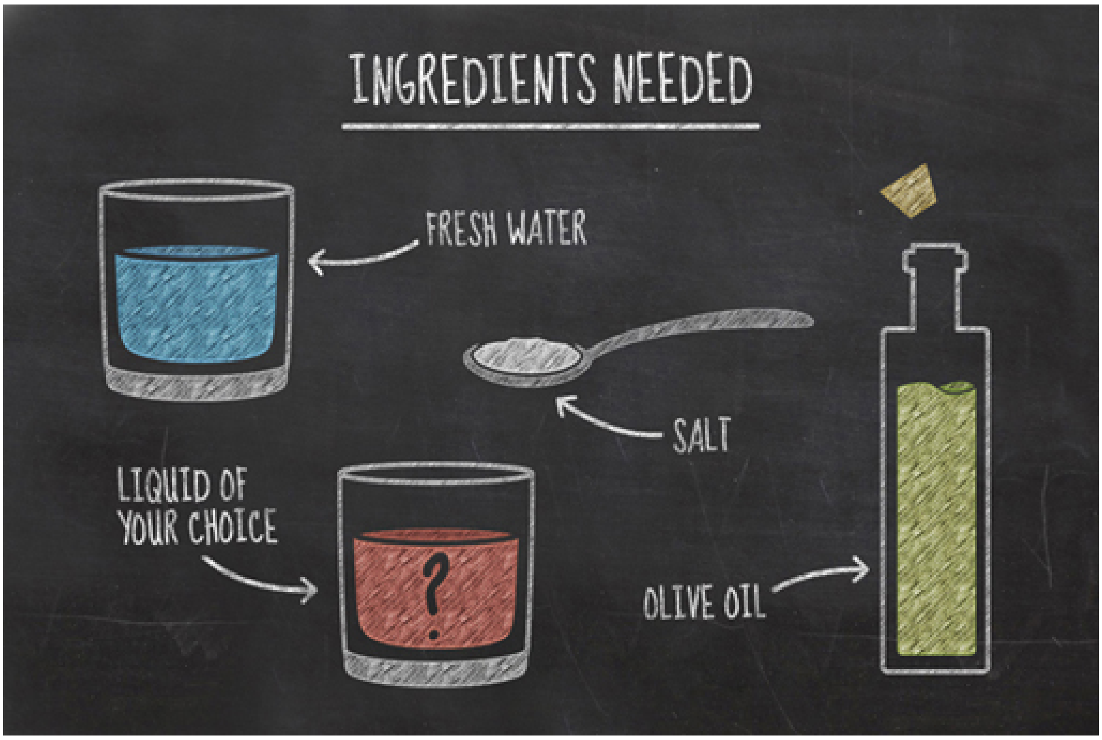

Figure 1

Solids, liquids and gases have very different properties that you will already be aware of on a practical level. For example:

- *solids* can typically be held and keep their shape
- *liquids* can flow, changing their shape to fill the space provided but without changing their volume
- *gases* are often invisible and change their shape and volume to fill whatever space is available.

The reason these states of the same material differ is to do with the behaviour of the particles (atoms and/or molecules) from which they are comprised:

- Particles in solids are packed together closely, held by strong forces called bonds. The particles can vibrate but they cannot move around freely, so a solid holds its shape.
- Particles in liquids are arranged randomly and are still held together by bonds, but the bonds are weak enough to allow the particles to move around each other.
- Particles in gases are further apart and are not held together by bonds. This allows the gas particles to move freely in all directions, expanding to fill the space they occupy.

Under special conditions, things can exist in all three states at the same time. Mostly though, only one or two states are seen at the same time. The most obvious example is for water, which, at standard pressure is a liquid at room temperature but a solid (ice) at temperatures below 0 °C, and a gas (steam) above 100 °C.

This week's experiment is all about the physical properties of different household liquids and how they change when they are frozen. You will also investigate whether or not the frozen liquid sinks or floats when placed into its own liquid form at room temperature.

Many of you will have performed part of this experiment already, perhaps adding an ice cube or two to a glass of water to cool it down. What happens when you add these ice cubes to your glass of water? Does the ice cube sink or does it float?

To conduct this experiment, you will need:

- an ice cube tray
- fresh water
- salt water (approximately 2 tablespoons of salt added to 500 ml of water)
- olive oil
- another liquid of your choice – be creative here, but avoid substances which might be hazardous!
- four glasses
- your activity booklet
- a freezer.

Before beginning an experiment scientists often use their previous experiences or preconceptions to *hypothesise* about the results of an experiment. For example, we know that ice floats on water, so a scientist might then hypothesise that the solid state of all the other substances will also float on their liquid counterparts.

You will notice that we have only specified three liquids (water, salt water and olive oil); however, you should choose a fourth liquid yourself. This is a chance for you to be creative. Look around your home and see what you can find.

What other liquid are you going to test? And what hypothesis can you make? Did you use any previous experiences or preconceptions to make this hypothesis? Post your ideas below. Scientists are curious folk with lots of ideas and interests, so explore your inner scientist.

2.1.1 The experiment

Have you got all the equipment you need? Follow Janet's instructions in the video (or use your activity booklet PDF) to conduct the experiment.

Video content is not available in this format.

As with any science experiment, it is important to keep detailed notes and to label your ice tray and glasses so you can keep track of the different parts of your experiment. Your activity booklet has a diagram of the ice cube tray to help you with recording this information.

Last week, you learned that variables are the factors than can be controlled, changed or measured in an experiment. What variables can you think of that might alter these results? Write these down, they might be useful later. Remember, this is an observational experiment – try taking photographs of your experiment. This will help you to remember the results later and allows you to share your results with your fellow learners.

You will have the opportunity to discuss your results in the next section.

2.1.2 Discussing your results

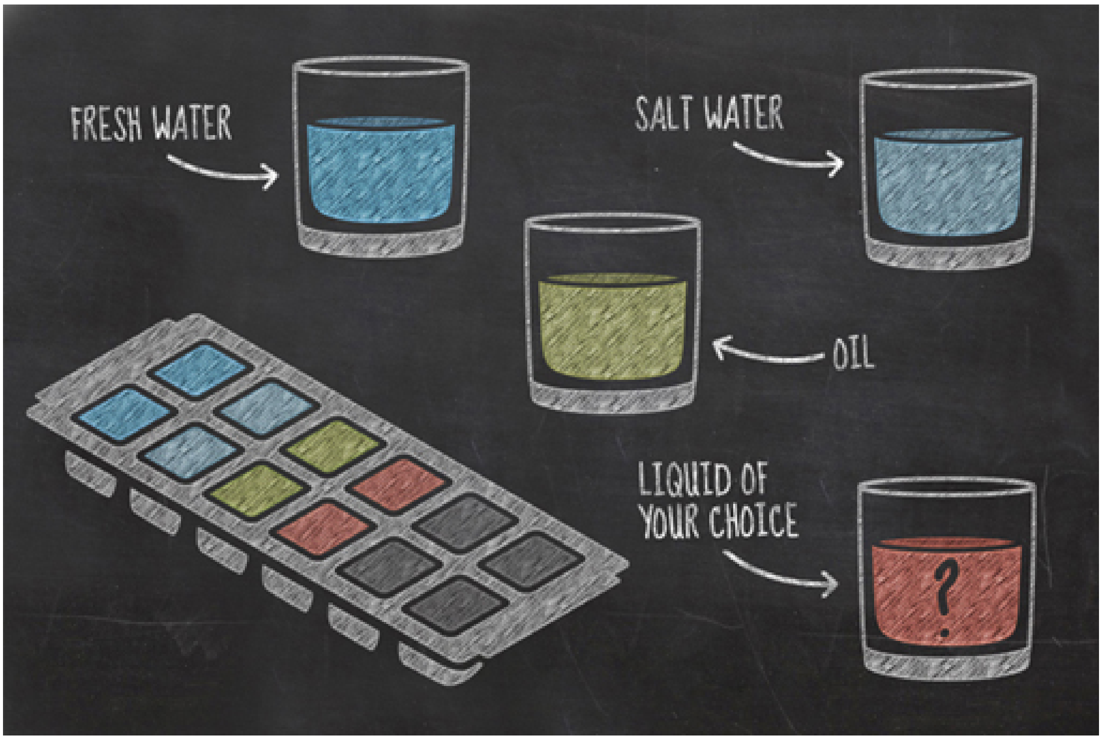

Figure 2

You should have now completed this week's experiment and be ready to share your findings with your fellow learners.

Activity 2.1 Experiment 3

Allow about 15 minutes

Post your results and findings in the course forum thread for this activity. If you would like to share an image of your experiment, you can do this by photographing or scanning your graph and attaching the photograph file with your forum post.

- Did the water, salt water and oil behave the same way as Janet's did?
- Did the liquid you chose yourself perform how you expected?
- Can you think of any other substances where the solid state would float on top of the liquid state, like water?
- Why do you think the ice floated, while the frozen oil did not?

Remember, science is often about collaboration – did other learners have broadly similar or vastly different results? Why do you think that might have been?

2.1.3 Ice tray experiment explained

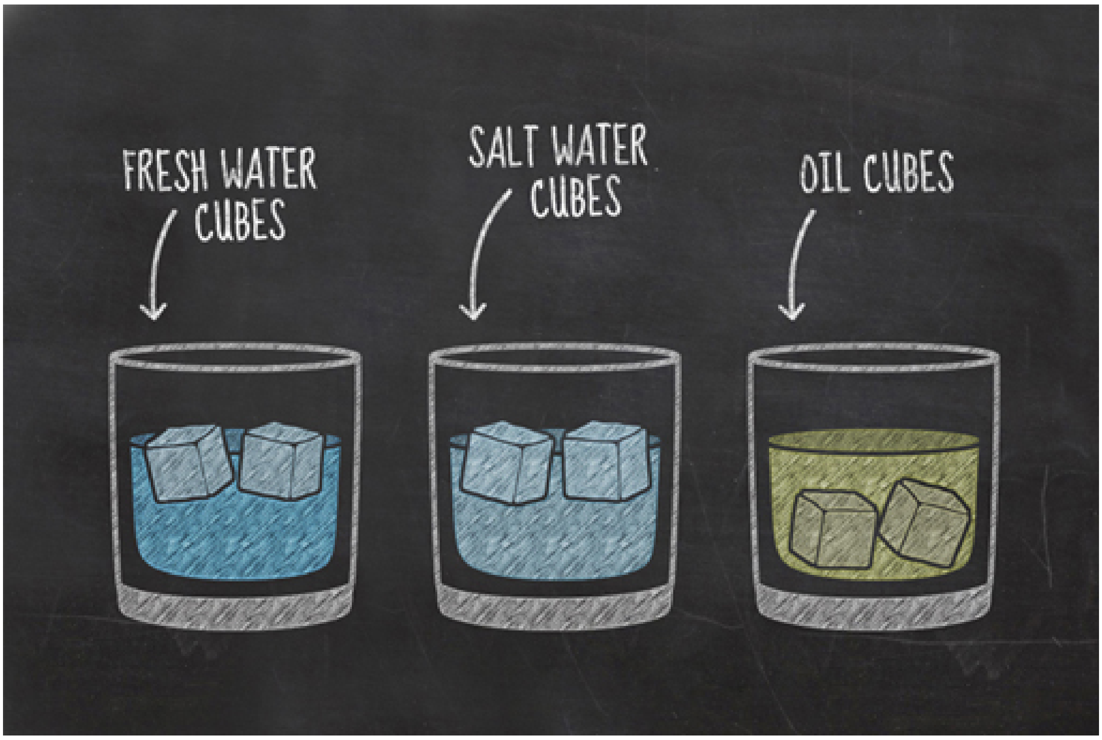

Figure 3

The simple experiment you performed this week has revealed some interesting properties about different liquids. You will probably have seen that the water-based cubes floated, while your other choices sank. While you might be more familiar with water ice floating on liquid water, this is actually a very unusual physical property, and our guess is that whatever liquid you froze for your fourth glass, like the oil, sank within its liquid form.

To understand these results, we first need to understand the physics behind whether objects float or sink at all. This relates to the object's density.

Density is a concept that sometimes confuses people, but it is simply the amount (mass) of something that is contained within a certain volume of space. For example, if you have one person in an elevator, it is not densely packed, but if you try and squeeze ten people in, things are going to get a bit tight. In this case the number of people is the amount, or mass, while the elevator is the volume of space. Mass is typically measured in grams, or kilograms, while volume is typically measured in cm^3 or m^3, so the units for density are usually g/cm^3, or kg/m^3.

It is the contrast between the density of the liquid and the density of the frozen cube which is important in determining whether that cube floats or sinks.

Earlier this week, you learned about the differences between solids, liquids, and gases. When most liquids freeze the individual atoms and molecules move closer together, allowing more to fit into a given volume. As a result, these substances are more compact in their solid state than in their liquid state, in other words, their density increases.

This is why the frozen oil and frozen honey sank in Janet's experiment. What is it about water that made it behave differently?

When water freezes, the molecules of water stick together in an unusual hexagonal structure which spaces them further apart as a solid than as a liquid. This makes ice less dense than water, and is why ice floats. Very few liquids are denser than their solids. Gallium, bismuth, antimony and germanium are four other examples, but they’re not very common. This is why we felt safe to assume that whatever liquid you froze for your fourth glass also sank.

2.2 What if ice was denser than water?

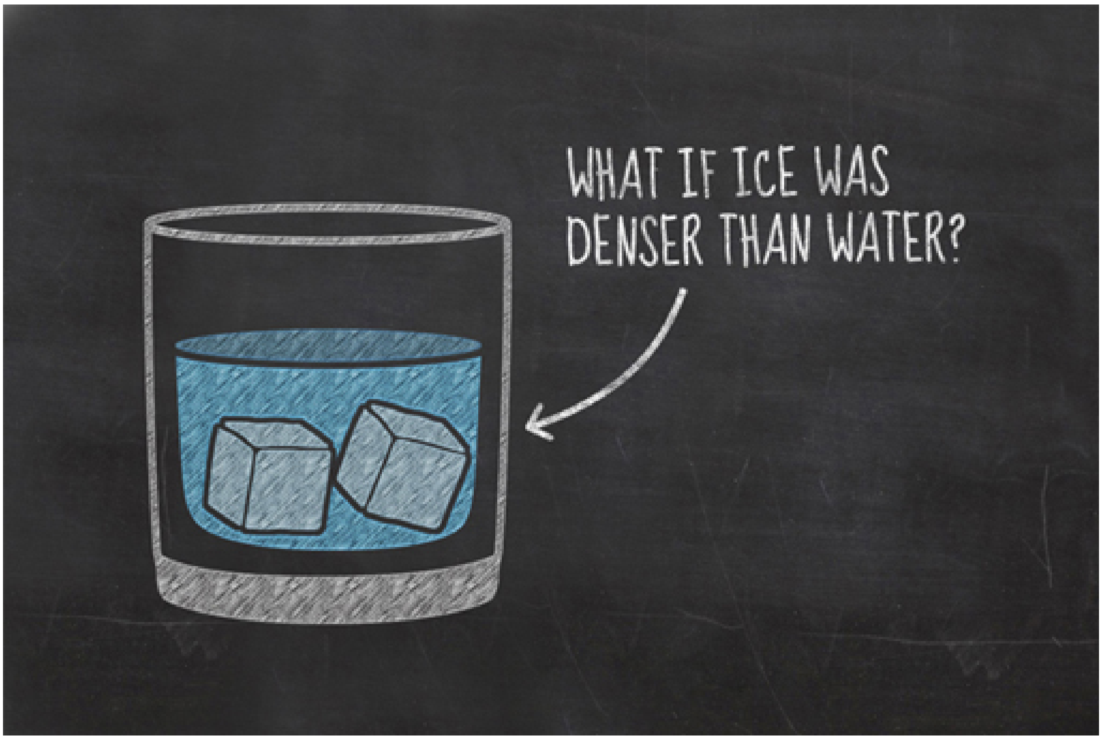

Figure 4

You've seen that water's unusual property of being less dense as a solid than as a liquid leads to ice floating on water.

Think about how surface ice might affect things like aquatic life, water temperature, oxygen levels and circulation patterns.

Imagining a world where ice was denser than water and sank, rather than floated, consider these questions:

- What might the consequences be for aquatic life?
- How might denser ice affect small-scale bodies of water, like ponds and lakes?
- How might denser ice affect oceans?
- Could denser ice have far-reaching effects on the evolution of life?

2.3 Week 2 quiz

Check what you’ve learned this week by taking this end-of-week test.

Complete the Week 2 quiz now.

Open the quiz in a new window or tab then come back here when you're done.

2.4 Week 2 summary

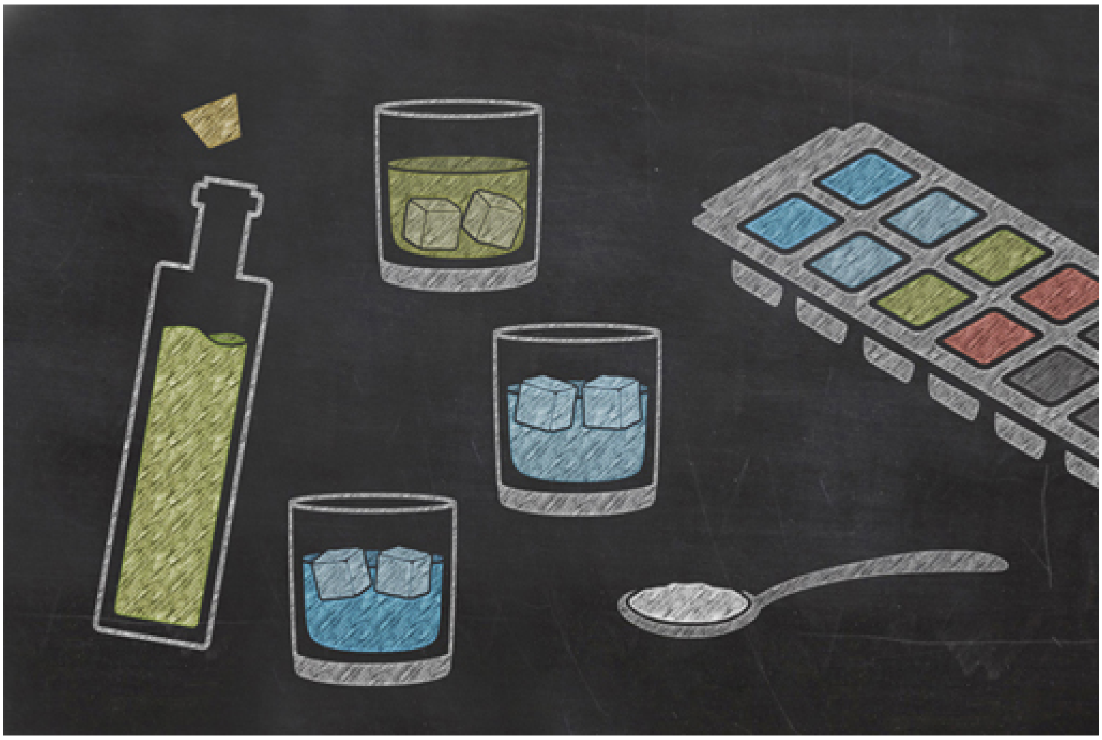

Figure 5

Congratulations on completing Week 2. Many of you will have certainly added ice cubes to your drink on a warm summer day and noticed that your ice cubes float at the top of your glass. As such, the starting point of this experiment was probably not much of a surprise. In carrying out this experiment, you became a real scientist and tested the hypothesis that other liquids will also behave in this fashion. Like a real scientist, you may have been confronted by results which proved your theory wrong and led you to question why that might be.

Hopefully you have learned that many experiments are observational and do not involve numbers, but both require detailed notes along the way. You should have also learned some science too, and be able to answer scientific questions, such as:

- Why do things sink or float?
- Why does ice behave differently from other common liquids in their solid state?
- Why is this weird property of water important to life itself?

Next week, you will be investigating the conditions required for living organisms to survive. It is simply amazing that scientific investigations, which are so important to Earth and life as we know it, can be investigated in the safety of your home, using everyday equipment and ingredients you can find in your local supermarket.

To conduct next week's experiment, you will need:

- four glasses
- four sachets of baker's yeast
- sugar

- water
- a kettle
- a marker pen
- cling film
- your activity booklet.

You can now go to Week 3.

Week 3: Sugar, yeast and life

Introduction

Video content is not available in this format.

Welcome to Week 3. This week, you will be conducting experiments using living organisms. You might be wondering if you need special licences or ethics committee approval, but as the organisms involved are only single-celled fungi, you don't need to worry. This week, you will be experimenting on yeasts.

As single-celled organisms, yeasts are tiny; only a few, to a few tens, of micrometres (10^{-6} m) across. Yet despite their size, they have had a huge impact on our culture, having been used for thousands of years in the manufacture of leavened bread, beer and wine (although some of us think it reached its culinary peak in the manufacture of Marmite).

The uses we have put yeasts to might seem trivial, but for many centuries throughout the history of human culture, water supplies were often unsafe to drink, due to the presence of pathogens. It was often the case that the only safe beverage to drink was beer or wine, so the use of yeasts has been pivotal in lowering mortality rates.

3.1 Experiment 4: Yeast experiment

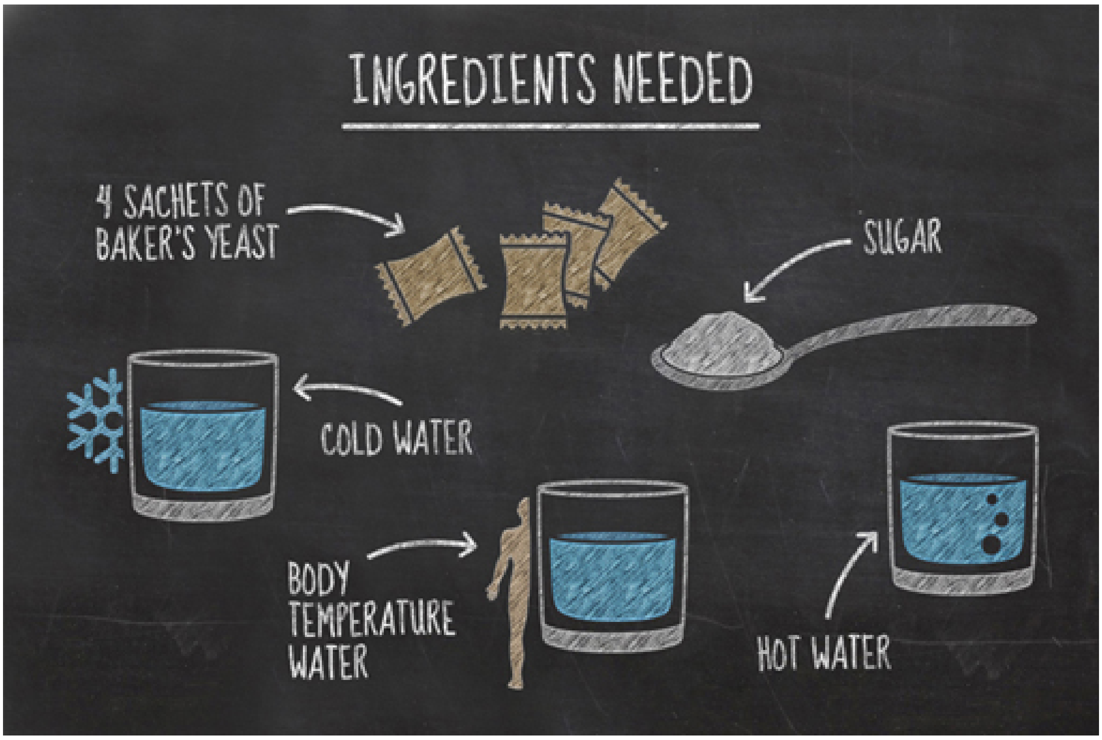

Figure 1

Living organisms, like yeasts, need food and oxygen in order to survive and thrive. In this experiment, you will test some conditions that can affect their growth. What variables might you be able to change in this experiment?

You will add the living yeast organisms to sugary solutions at different temperatures. You will also cover one glass of your sugary solution with cling film.

To carry out this experiment, you will need:

- four glasses
- four sachets of baker's yeast
- sugar
- water
- a kettle
- a marker pen
- cling film
- your activity booklet.

As with experiments in the previous weeks, you will want to carry this out somewhere that it won't be disturbed by family members or pets. The experiment shouldn't take more than half an hour or so to carry out, so you won't need to be vigilant for too long.

What results do you expect to see in this experiment? Try to write down a hypothesis that you will be testing.

3.1.1 The experiment

Follow Janet's instructions in the video (or use your activity booklet PDF) to conduct the experiment. You will need about 1 tablespoon of sugar and approximately 200 ml of water in each large glass. This sugar will act as food for your yeasts to consume.

Video content is not available in this format.

Take care to label your glasses with which variables you've changed – you don't want to get them mixed up. If the environmental conditions are suitable, the yeasts will grow and multiply quite quickly – you shouldn't need more than 30 minutes to complete this experiment. Remember that boiling water can crack glassware, so be careful to let the water cool a bit first.

Carefully observe and record which glasses have conditions suitable for the yeasts to grow and which ones have conditions that restrict its growth.

You will have the opportunity to discuss your results in the next section.

3.1.2 What were your results?

Figure 2

You should now have completed this week's experiment and be ready to share your findings with your fellow learners.

Activity 3.1 Experiment 4

Allow about 15 minutes

Post your results and findings in the course forum thread for this activity

- Were your results similar to Janet's or were there any differences?
- Which environments promoted yeast growth and what environments hindered yeast growth?
- How do the results of your two experiments at body temperature conditions compare?
- Did you notice any changes with time? If you needed to, how could you display these results?

While it is nice when an experiment goes according to plan, it is often more interesting from a scientific point of view when something odd and unexpected happens. It usually means that there is something exciting going on, or that you need to think about ways to tighten up your experimental skills – both of which are good things. Never feel bad if an experiment goes a bit wonky, that is where the cutting edge stuff happens!

3.1.3 Yeast experiment explained

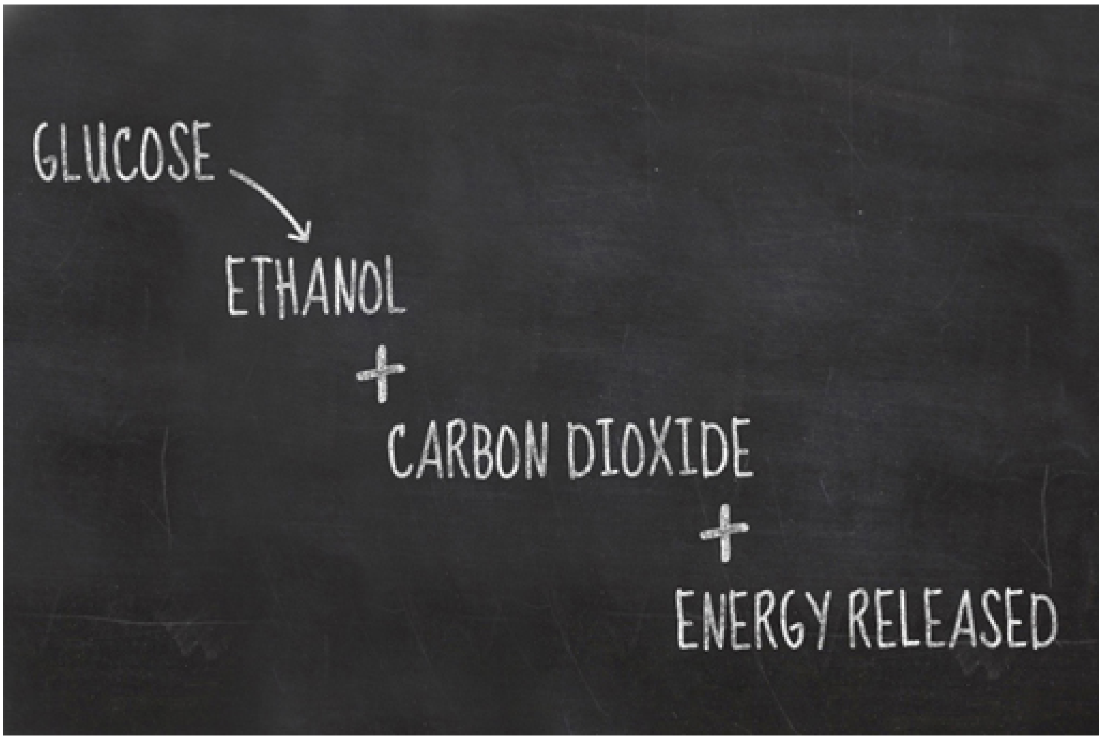

Figure 3

You've seen the results of the yeast experiment, but what do these results mean?

Yeasts are microscopic, single-celled organisms, and are a type of fungus that is found all around us, in water, soil, on plants, on animals and in the air. Like all organisms, when yeasts are put in the right type of environment they will thrive; growing and reproducing.

Your experiments were designed to help you identify which environment promotes the most yeast growth. The first three glasses in your experiment contained different temperature environments (cold water, hot water and body temperature water). At very low temperatures the yeast simply does not grow but it is still alive – if the environment were to warm up a bit, it would gradually begin to grow. At very high temperatures the cells within the yeast become damaged beyond repair and even if the temperature of that environment cooled, the yeast would still be unable to grow. At optimum temperatures the yeast thrives.

Your third and fourth glasses both contained environments at optimum temperature (body temperature) for yeast growth, the difference being, the fourth glass was sealed. The variable between these two experiments was the amount of available oxygen. You may have been surprised by your results here, thinking that a living organism in an environment without oxygen cannot survive? However, you should have found that yeast grew pretty well in both experiments.

To understand why yeast was able to thrive in both conditions we need to understand the chemical process occurring in each glass during the experiment. In the three open glasses, oxygen is readily available, and from the moment you added the yeast to the sugar solution it began to chemically convert the sugar in the water and the oxygen in the air into energy, water, and carbon dioxide in a process called aerobic respiration.

Yeast is a slightly unusual organism – it is a ‘facultative anaerobe’. This means that in oxygen-free environments they can still survive. The yeast simply switches from aerobic respiration (requiring oxygen) to anaerobic respiration (not requiring oxygen) and converts its food without oxygen in a process known as fermentation. Due to the absence of oxygen, the waste products of this chemical reaction are different and this fermentation process results in carbon dioxide and ethanol.

Depending on how long you monitored your experiment for and how much space your yeast had to grow you may have noticed that, with time, the experiment sealed with cling film slowed down. This is for two reasons; firstly because less energy is produced by anaerobic respiration than by aerobic respiration and, secondly, because the ethanol produced is actually toxic to the yeast. As the ethanol concentration in the environment increases, the yeast cells begin to get damaged, slowing their growth.

The ethanol produced is a type of alcohol, so it is this process that allows us to use it to make beer and wine. When used in bread making, the yeast begins by respiring aerobically, the carbon dioxide from which makes the bread rise. Eventually the available oxygen is used up, and the yeast switches to anaerobic respiration producing alcohol and carbon dioxide instead. Do not worry though; this alcohol evaporates during the baking process, so you won’t get drunk at lunchtime from eating your sandwiches.

3.2 Altering variables

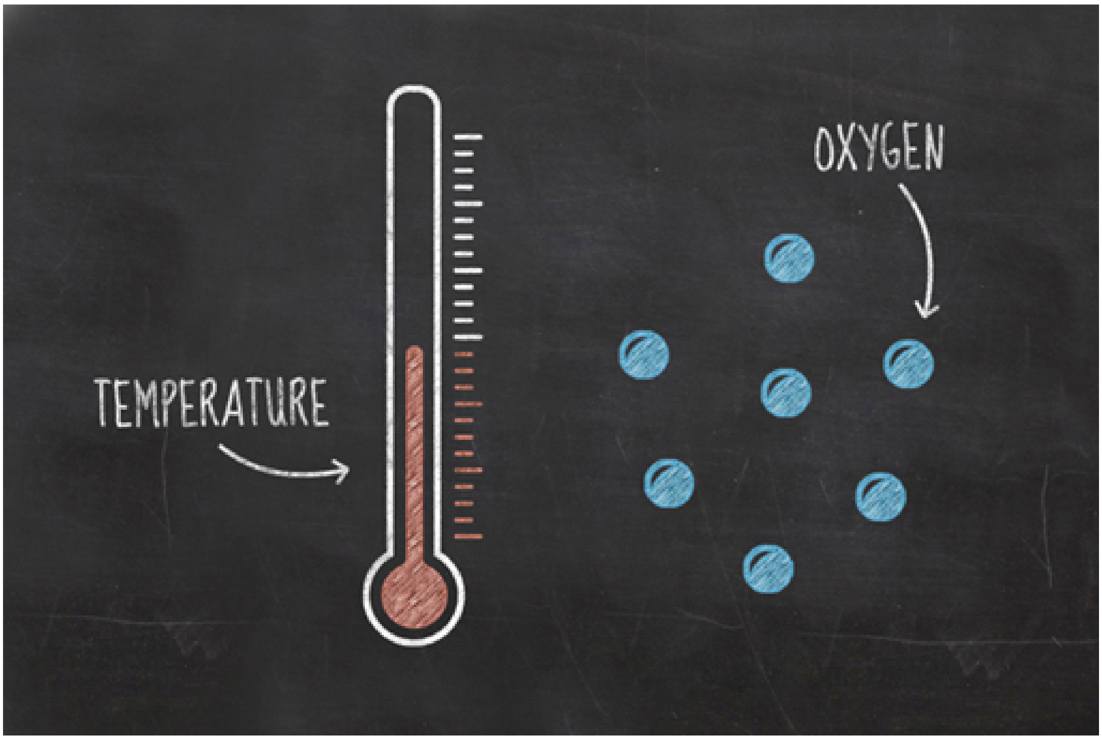

Figure 4

You have now conducted another experiment, one which had several different variables. Variables are parts of an experiment that can be kept the same, or changed in order to test different outcomes.

In the yeast experiment, you actually performed two separate tests at the same time; one regarding the temperature and another regarding available oxygen. Note that in each case you only altered one variable (either temperature or oxygen availability).

You could repeat the yeast experiment, keeping both temperature and oxygen availability constant but altering a different variable, i.e., fixing a previously changing variable and changing a previously fixed variable. By performing a combination of these experiments the optimum conditions for yeast growth can be determined.

You should now be starting to think like an experimental scientist and considering ways that an experiment can be altered so that different hypotheses can be tested.

Takes some time now to think which other variables you could test and why.

3.3 Yeast – who needs it?

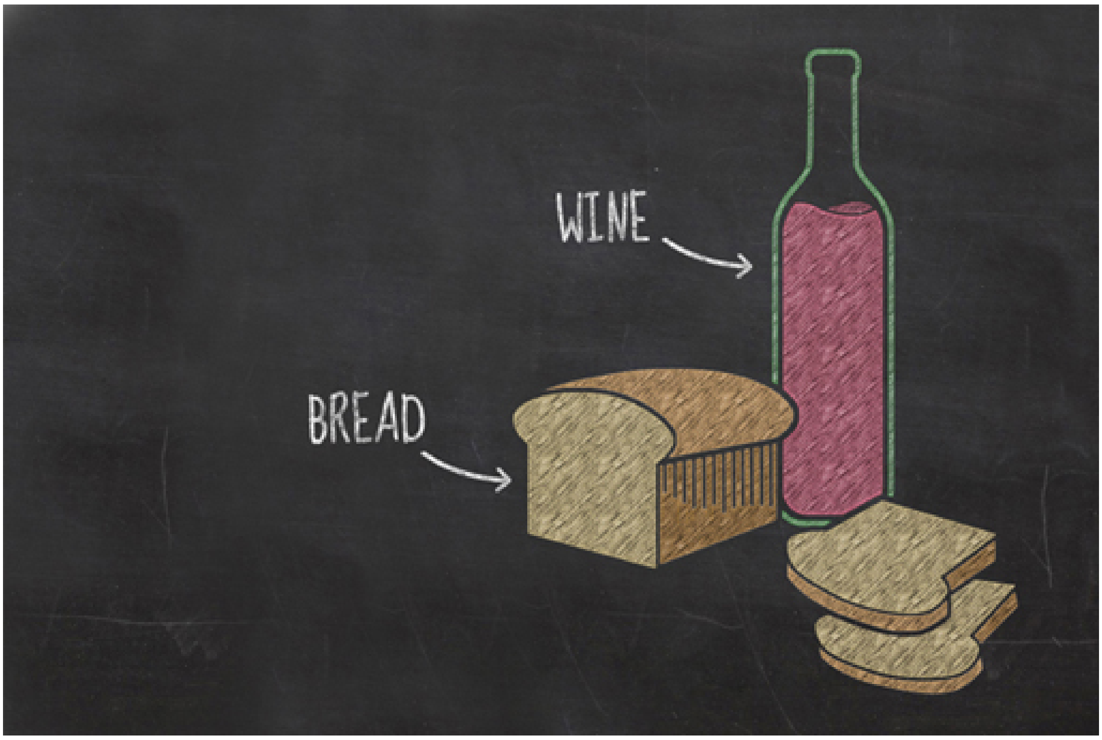

Figure 5

You've seen yeast in action and had a look at the science behind it, but where has it come from? Human society has used it for at least 7000 years. Its use in brewing is first thought to have taken place in ancient Iran and possibly even earlier in China. The oldest surviving beer recipe dates back to a 3900-year-old Sumerian poem.

The earliest brewing may well have been accidental, as wild yeasts in the air and on the ground may have contaminated cereal crops, causing them to undergo spontaneous fermentation, possibly in leftover pots of gruel. As time passed these brews would have been replicated and, to a degree, standardised.

Without fermented beverages, historical populations might have been afflicted with more waterborne diseases than are recorded, due to the boiling step in the production process.

Around the same time yeasts were being used in brewing, they began to be used as raising agents in bread making. As far back as 30,000 years ago, humans were crushing up cereal crops and baking them as flatbreads, but records show that from a few thousand years ago the ancient Egyptians began using yeasts to leaven bread, although the extent to which their rather dense loaves actually rose is uncertain.

The Romans, Greeks, Gauls, and Iberians are all recorded as making leavened breads. By the Middle Ages bread had become a staple across Europe, not only as food, but also as a type of plate, known as a trencher. These trenchers were made from a slice of stale bread, on which the food was placed. The trencher would soak up the juices to be eaten later or given to the poor.

In modern times, bread comes in a dizzying array of types, light to dark, pure and refined, coarse and grainy, sliced and unsliced to name but a few. Interestingly, sliced bread is a fairly recent invention.

Early attempts to pre-slice bread were met with doubt as it was thought that the bread would go stale too quickly. In 1928, Otto Rohwedder sold his latest invention to a bakery in Chillicothe, Missouri, a device to slice and wrap loaves of bread. In 1928, an advert was run on the back page of the local newspaper proclaiming it to be ‘the greatest forward step in the baking industry since bread was wrapped’. This may be the origins of the phrase, ‘the best thing since sliced bread’, suggesting that the best thing prior to sliced bread was wrapped bread!

3.4 Week 3 quiz

Check what you've learned this week by taking this end-of-week test.

Complete the Week 3 quiz now.

Open the quiz in a new window or tab then come back here when you're done.

3.5 Week 3 summary

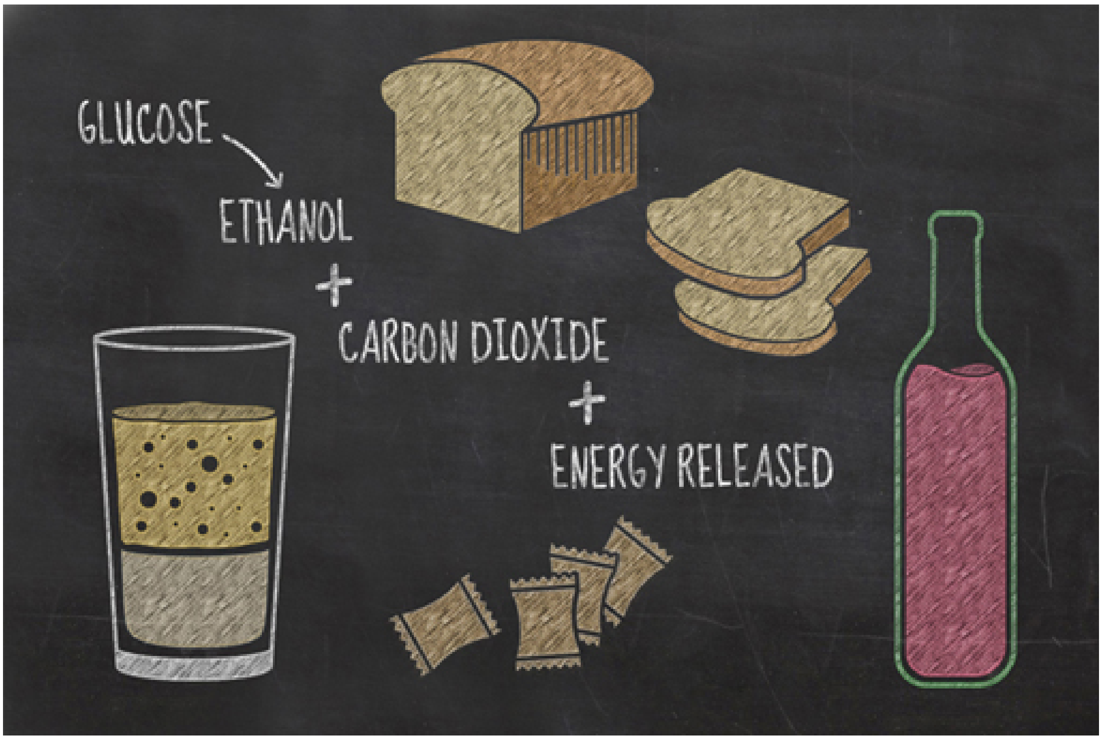

Figure 6

Congratulations on completing Week 3. Who knew yeast was so important in human history?

While the experiments you've carried out over the last three weeks have been necessarily simple enough for you to perform at home, with little risk of accidentally constructing a doomsday device or incinerating your pets or family, they are important experiments in explaining how the world around us works. Hopefully, you've also developed skills in carrying out scientific experiments and how you can identify and alter variables to test a hypothesis further.

In the final week of the course, the difficulty level ramps up a notch, as you will be using some household items to separate and extract the DNA from a living organism!

To conduct next week's experiment, you will need:

- kiwi fruit (or another fruit of your choice)
- methylated spirits, chilled in freezer for 30 minutes (or vodka or strong white rum)
- fine sieve or filter paper
- salt
- washing-up liquid
- measuring beaker
- a paperclip.

Remember, methylated spirits are extremely hazardous and should only be used with adult supervision.

You can now go to Week 4.

Week 4: DNA

Introduction

Video content is not available in this format.

Welcome to Week 4. This week, you are going to use some fairly common household chemicals to isolate and observe the DNA (deoxyribonucleic acid) from the nucleus of a kiwi fruit.

DNA was first isolated as far back as 1869, but it wasn't until 1928 that scientists realised that it carried genetic information. In 1953, the structure of the molecule was discovered by Francis Crick and James D. Watson and other colleagues, while working at Cambridge University.

DNA is a molecule containing sequences of chemicals in very specific arrangements. The shape of the molecule is like a twisted ladder, known as a 'double helix', which contains stretches of chemicals, known as genes, which code for certain biological traits and functions. In other words, DNA contains the instructions by which organisms build and maintain their existence.

4.1 Experiment 5: Kiwi experiment

Figure 1

In humans, the DNA molecule is very long and thin. It is about 2.5×10−9m across, yet if it were stretched out, it would reach up to 2 or 3 metres in length. Within the cell, the molecule is twisted and coiled, like earphone cables kept in a coat pocket. In fact, there is enough DNA in your cells to reach to the Sun and back about 65 times.

Fortunately for us, this experiment won't require you to build a spaceship and test that fact. For this experiment, you are going to use some fairly common materials to extract the DNA from the cells of a kiwi fruit. Once the DNA is isolated and clumped together, there will be enough for you to see without microscopes or high-tech equipment and it can also be carefully removed with nothing more than a paper clip.

We will keep referring to a kiwi fruit throughout the week, as this is an easy example to obtain and to work with, but you can use other soft fruits if you wish. Remember, you will then be altering a variable, and should be ready to discuss how it affects your results.

To carry out this experiment, you will need:

- a kiwi fruit (or another fruit of your choice)
- a peeler/knife (to remove the skin/peel)
- a fork
- methylated spirits, chilled in freezer for 30 minutes (or vodka/strong white rum)
- a fine sieve or filter paper
- a couple of bowls
- salt
- tap water
- warm water

- washing-up liquid
- teaspoon
- measuring beaker
- a couple of glasses
- a paperclip.

Remember, methylated spirits are extremely hazardous and should only be used by adults or with adult supervision.

4.1.1 The experiment

Have you chosen which fruit you're going to extract DNA from? Follow Janet's instructions in the video (or use your activity booklet) to conduct the experiment.

Video content is not available in this format.

Remember that vodka and rum are strongly alcoholic and, in the case of methylated spirits, also highly toxic. The ethanol in them is also highly flammable. You should also take care when you peel and chop your kiwi fruit: you don't want any bits of finger mixed in with the fruit!

Although you are performing this experiment in your home, it actually follows the same basic principles as more advanced lab-based DNA extraction procedures, so you are, in effect, doing something that scientists in labs do every day.

The procedures you are going to carry out are:

- the mechanical and thermal disruption of the cells
- the liberation of the DNA with an extraction buffer
- the precipitation of the DNA.

As you perform the experiment, you should recognise each of these stages taking place. The mashing and heating of the kiwi mixture represents the mechanical and thermal disruption of the cells. The washing-up liquid and salt water mixture forms your extraction buffer and both work to liberate the DNA, in other words remove it from the cells. The detergent works just like it does on your dishes and dissolves the lipids (fats) in the cell membranes and nucleus where the DNA currently resides.

DNA is highly soluble in water but not soluble in ethanol (alcohol). When you add the alcohol to the top of your kiwi mixture, the DNA precipitates (or deposits in a solid form) at the interface between the water and the alcohol. The salt that you added earlier helps encourage the DNA to clump together by neutralising the negatively charged phosphate groups that exist within the DNA structure.

When you have finished the experiment and extracted the DNA, move to the next section to discuss your results.

4.1.2 What were your results?

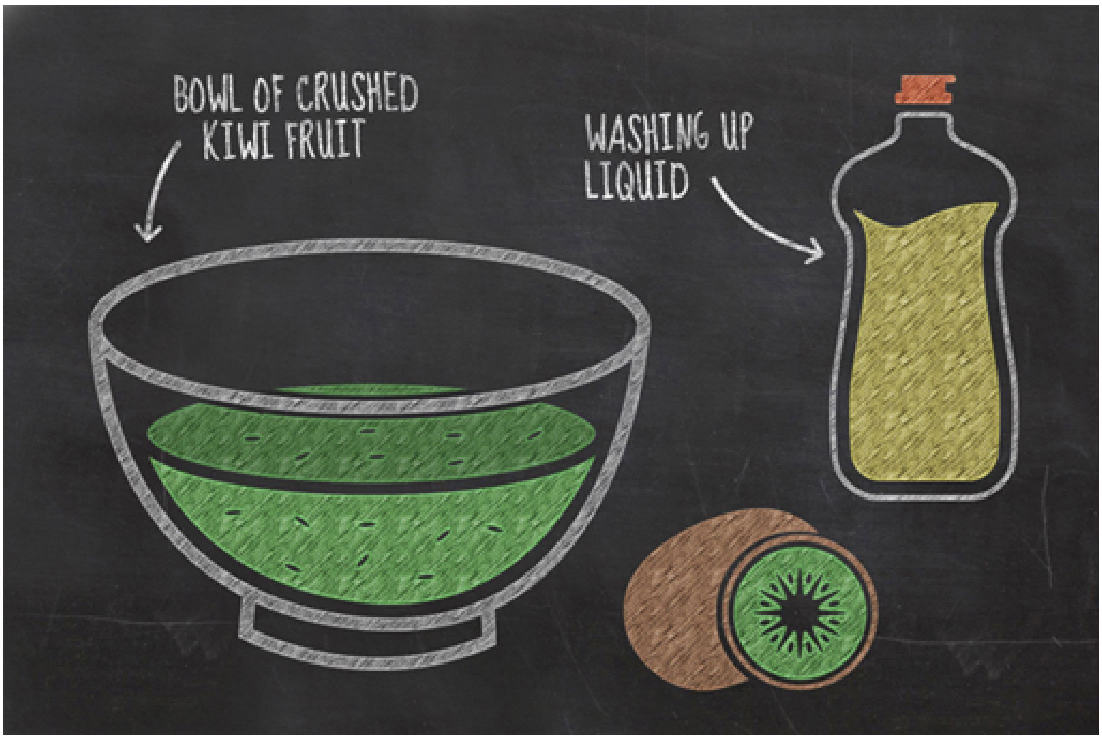

Figure 2

You should now have completed this week's experiment and be ready to share and discuss your findings with fellow learners.

Each glob of the white goo in your glass contains millions of DNA strands, clumped together. If you had your own research laboratory, you would be able to analyse the goo and show that this is in fact DNA. Unfortunately, research laboratories are not commonly found at home so you will just have to take our word for it!

Activity 4.1 Experiment 5

Allow about 15 minutes

Post your results and findings in the course forum thread for this activity. Photographs can really help here, so take advantage of being able to attach images to your forum post.

- Did the experiment work in the way that you expected?
- Did you try a different fruit or alcohol to Janet? How did this affect your results?

4.2 Why does it matter?

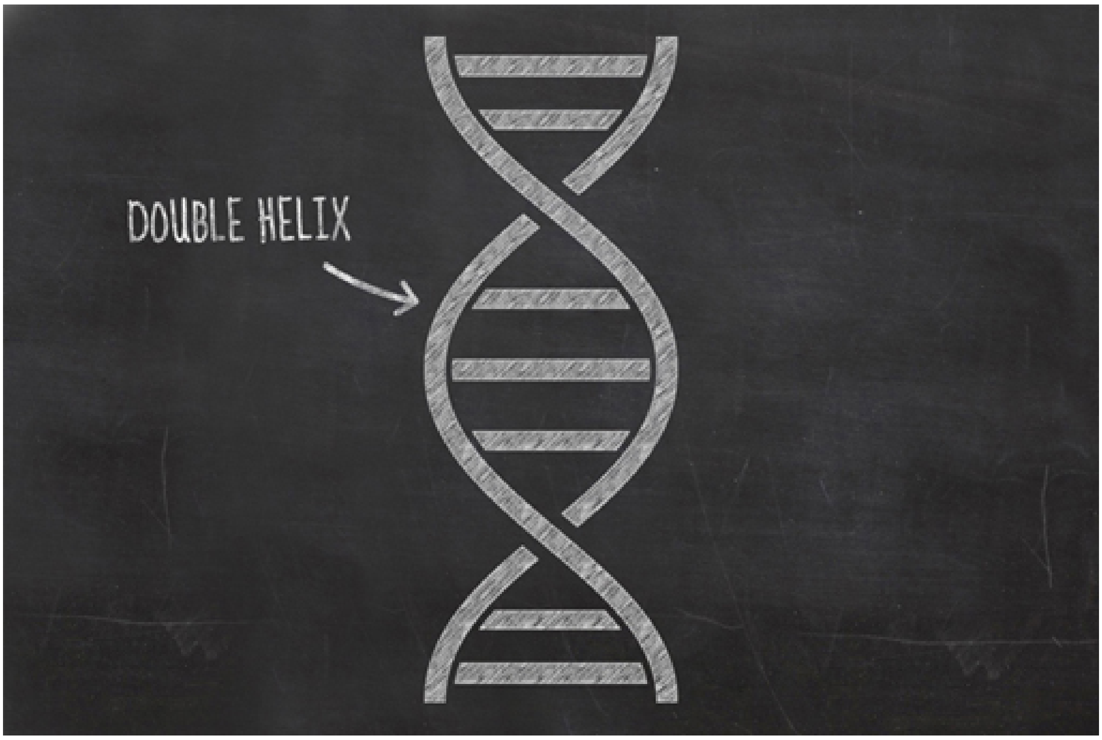

Figure 3

You've now extracted DNA from an organism, but why is this important? In carrying out this experiment, you have taken the first step in all experiments that work with DNA. While you are limited in the types of DNA research you can perform in your kitchen, it is possible to take this much further with a fully equipped laboratory. For example, once scientists have isolated the DNA from an organism, they can use it to clone a sheep, solve a murder, test for paternity, create an insect-resistant crop or cure a disease.

An important line of DNA research is pharmacogenomics, which concentrates on the role of genetics in drug response because different people respond differently to the same medical treatments. It is hoped that if a treatment can be tailored to our genetic signature, it will be more effective at curing whatever ails us and have fewer adverse side-effects. For example, a common chemotherapy treatment for cancer involves the chemical mercaptopurine, which kills tumour cells, but the side-effect is that mercaptopurine is toxic. This is not usually too much of a problem as patients produce an enzyme called TPMT (thiopurine methyltransferase), which breaks down the mercaptopurine before the levels in the blood get too high. A tiny percentage of patients produce TPMT too slowly, and suffer toxic side-effects to the drug. By studying the DNA of a patient, doctors can attempt to determine how extreme a reaction they will have to the drug and can prescribe a more appropriate dose.

Aside from using genetic information to assist in choosing the most appropriate treatment, doctors can also look at a patient's DNA to identify risk factors to particular diseases and conditions in order to advise the patient in taking suitable preventative measures.

Many other types of scientific research revolve around the use of DNA. These include:

- Forensic science, where the identification and analysis of DNA from crime scenes is used to identify and exclude suspects.
- The genetic modification of organisms, most commonly in agriculture where the goal is to improve yields.
- Paternity testing, where DNA is used to identify the real father or exclude other possible fathers.
- Food safety, in relation to the correct labelling of meat products.
- Artificial cloning, most famously Dolly the sheep, but many other mammals and amphibians have been cloned.

Jurassic Park brought the subject of artificial cloning to attention of the population at large through Lord Richard Attenborough's character who created a dinosaur theme park. It turns out that the story contained a certain amount of 'poetic license'; DNA simply doesn't survive that long. In fact, even under ideal preservation conditions, it has been calculated that the absolute maximum time after death that DNA can be successfully extracted from a deceased organism is about a million years. Jurassic Park may be a fantasy, but there is a very remote possibility that woolly mammoths could be brought back to life through the process of cloning, as the last of these died out only a few thousand years ago.

4.3 Week 4 quiz

By taking this end-of-course quiz you can check what you've learned across all four weeks of the course.

Complete the End-of-course quiz now.

Open the quiz in a new window or tab then come back here when you're done.

4.3 The beginning of your scientific career

Figure 4

Well done for completing this four-week course on understanding experiments! Over the past four weeks you've looked at:

- the process of osmosis how density changes between liquid and solid states of household substances
- how aerobic and anaerobic respiration works in yeast
- how to extract DNA from fruit using equipment you find in your kitchen
- the importance of keeping a scientific journal.

We've created an area on OpenLearn allowing you to take your study of experiments in science further.

Now you've completed the course we would again appreciate a few minutes of your time to tell us a bit about your experience of studying it and what you plan to do next. We will use this information to provide better online experiences for all our learners and to share our findings with others. If you'd like to help, please fill in this optional survey.

Acknowledgements

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