Cambridge Assessment International Education

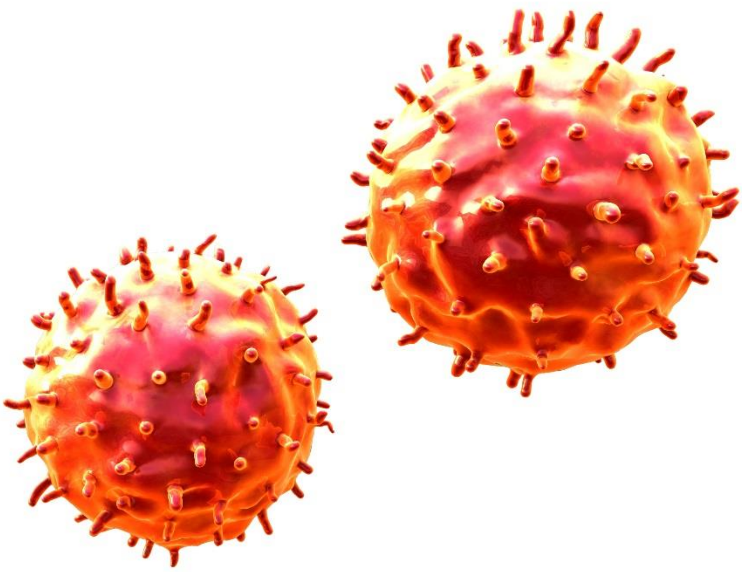
Teaching Pack

Investigating the effect of osmosis on plant tissues

Cambridge IGCSE™

Biology 0610

This *Teaching Pack* can also be used with the following syllabuses:
- Cambridge IGCSE™ (9–1) Biology **0970**
- Cambridge IGCSE™ Biology (US) **0438**
- Cambridge IGCSE™ Combined Science **0653** (2019–2021)
- Cambridge IGCSE™ Co-ordinated Sciences (Double Award) **0654**
- Cambridge IGCSE™ (9–1) Co-ordinated Sciences (Double Award) **0973**
- Cambridge O Level Biology **5090**
- Cambridge O Level Combined Science **5129**



Version 2.0

Cambridge Pathway

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Icons used in this pack:

Briefing lesson

Lab lesson: Option 1 – run the experiment

Lab lesson: Option 2 – virtual experiment

Debriefing lesson

Introduction

This pack will help you to develop your learners' experimental skills as defined by assessment objective 3 (AO3 Experimental skills and investigations) in the course syllabus.

> **Important note**
>
> Our *Teaching Packs* have been written by **classroom teachers** to help you deliver topics and skills that can be challenging. Use these materials to supplement your teaching and engage your learners. You can also use them to help you create lesson plans for other experiments.
>
> ***This content is designed to give you and your learners the chance to explore practical skills. It is not intended as specific practice for Paper 5 (Practical Test) or Paper 6 (Alternative to the Practical Test).***

There are two options for practising experimental skills. If you have laboratory facilities this pack will support you with the logistics of running the experiment. If you have limited access to experimental equipment and/or chemicals, this pack will help you to deliver a virtual experiment.

This is one of a range of *Teaching Packs*. Each pack is based on one experiment with a focus on specific experimental techniques. The packs can be used in any order to suit your teaching sequence.

The structure is as follows:

Briefing lesson (1 hour*)
This lesson introduces the focus experimental skills to be developed. It also introduces any content needed for your learners to understand the experiment being carried out in the *Lab lesson*.

↓

Lab lesson (1 hour*)	
Option 1 – run the experiment	**Option 2 – virtual experiment**
This lesson allows the experiment to be run with your learners, providing an opportunity to practise the experimental skills introduced in the *Briefing lesson*.	This lesson allows your learners to complete a virtual experiment, providing an opportunity to practise the experimental skills introduced in the *Briefing lesson*.

↓

Debriefing lesson (1 hour*)
This lesson consolidates and builds on the progress learners have made. In some cases, it will also provide the opportunity to practise extended writing skills.

** the timings are a guide only; you may need to adapt the lessons to suit your circumstances.*

In this *Teaching Pack* you will find the lesson plans, worksheets for learners and teacher resource sheets you will need to successfully complete this experiment.

Experiment: Investigating the effect of osmosis on plant tissues

This *Teaching Pack* focuses on the effect of osmosis on plant cells.

Osmosis is a specialised type of diffusion that is specific to water molecules. In this experiment you will determine what happens when potato cells are left in sucrose solutions of different concentrations. You will then explain this using water movement into and out of cells.

This experiment has links to the following syllabus content (see syllabus for detail):

- 3.2 Osmosis

The experiment covers the following experimental skills, adapted from **AO3: Experimental skills and investigations** (see syllabus for assessment objectives):

- planning a method
- interpretation of experimental observations and data
- evaluate methods and suggest possible improvements.

Prior knowledge

Knowledge from the following syllabus topics is useful for this experiment.

- 2.1 Cell structure
- 3.1 Diffusion
- 3.2 Osmosis

Going forward

The knowledge and skills gained from this experiment will be useful for when you teach learners about osmosis.

Briefing lesson: Evaluating methods

Resources	• 1 cm × 1 cm × 1 cm piece of potato • 1 cm × 1 cm × 1 cm piece of carrot • test-tubes × 2 (or other container) • tap water • balance / scale accurate to two decimal places • Worksheet A

Learning objectives	By the end of the lesson: • ***all*** learners should be able to state some causes of error in a given method • ***most*** learners should also be able to describe how to make a given method more accurate • ***some*** learners will also be able to explain how the method impacts the validity and reliability of results.

Timings	Activity
5 min	**Starter/introduction** Ask learners to think about what is meant by 'evaluation' in the context of a scientific investigation, and what its purpose is. Ask them to do this independently, and then discuss their thoughts with a partner. Open the discussion out to the whole class. Make sure learners understand that an 'evaluation' means to make a judgement about the investigation, considering its strengths and weaknesses. The purpose of evaluating an investigation is to determine if it was carried out in such a way that any conclusions made are trustworthy.
10 min 5 min	**Main lesson** Give learners Worksheet A. Show them the carrot and potato cubes. Make a point of saying they have the same volume. Put the carrot and potato into separate test-tubes of tap water. Explain that you will leave the samples for about 10 minutes. (The samples could already be set up ahead of the lesson and you just tell them what was done.) Ask learners to explain what osmosis is, remind them if necessary. (For Extended learners, talk about water potential and water potential gradients.) Ask learners what they think will happen to the mass of the carrot and potato given what they know about osmosis. Share learners' predictions as a class and correct any misconceptions on the theory of osmosis. Write a class hypothesis on the board. After 10 minutes, take out the cubes but do **not** dry them. Measure their mass. Learners work individually to interpret the results and think about what conclusions they can draw. Was their hypothesis correct? How do they know? Learners share their thoughts with a partner and then discuss as a class. Learners should recognise that they cannot make a conclusion about what has happened to the mass of the samples because they do not know what the starting mass was. This is a considerable weakness in the method. Tell them to note this down under the appropriate step on Worksheet A. *Continues on next page …*

Timings	Activity
15 min	**Main lesson continued …**

Ask learners if they can think of other weaknesses in the method. Suggestions should include: the samples weren't dried before their mass was recorded, so the mass will include excess water; the volume of tap water in the test-tubes wasn't measured so might not be the same (this should be a controlled variable); and the experiment was only done once.

Do they think the experiment was valid and reliable? Explain that in a valid experiment, the results obtained are due *only* to the independent variable (i.e. the one being investigated) and nothing else. A reliable experiment is one that would lead to the same/very similar result each time. Make sure the discussion also includes strengths of the method. Strengths and weaknesses can be jotted down on Worksheet A under the appropriate step in the method.

Ask what the advantages and disadvantages would be of measuring the volume of the samples after submersion instead of the mass. Possible disadvantages include: it's more time-consuming than measuring the mass; and that there's more room for error to be introduced: you can't guarantee that each measurement will be taken with the same accuracy due to human nature (whereas a balance will always have the same degree of accuracy); also, measuring the volume requires a calculation, which is another possible place that error can be introduced. An advantage includes that excess water on the surface won't affect the results and at these small masses, the error caused by excess water could be larger than the changes in mass of the plant tissue being measured.

Explain that the most appropriate method is based on what you're trying to find out, how long you have available and how accurate the result needs to be. For example, a balance with accuracy of the nearest gram would not be accurate enough to detect any differences in mass in such small samples, whereas one that is accurate to 4 decimal places would give valid results but should show unnecessary detail.

15 min

Explain to learners that you want them to plan a similar experiment to determine which vegetable takes up the most water in 10 minutes. In column 1 of Worksheet A are the steps of the method you showed them. Ask learners to spend about 5 minutes summarising the improvements they would make to the method based on the discussions they've just had. They should write their new method in the second box/column; they can include new steps as well as amending existing steps. Encourage them to justify their decisions.

Discuss and agree the changes as a class (see suggested answers).

Tell them the starting mass of each sample is as follows.

Mass of potato / g	Mass of carrot / g
10	2
9	6
7	5

Ask if there are any other changes to the method they would make now that they've seen the starting masses. If no one suggests it, ask learners to consider if simply measuring the change in mass is the most accurate method given that the starting masses of each sample are quite different. For example, if a potato cube with a mass of 10 g increases in mass by 1g but a carrot cube with starting mass of 2 g increases in mass by 0.8 g, how can you compare them accurately?

Continues on next page …

Timings	Activity
	Main lesson continued … An increase of 1 g is more than an increase of 0.5 g but 1 g is a much smaller proportion of 10 g than 0.8 g is of 2 g; which suggests that the carrot was actually affected more by osmosis than the potato even though the change in mass was smaller. A larger change in mass might be recorded because a sample started with a bigger surface area for osmosis to occur compared to a smaller sample. Therefore, there are effectively two variables being tested: sample size and plant type; and this would make the experiment invalid. Introduce the idea of improving the accuracy of the results by measuring the percentage change in mass. A percentage is a proportion and will demonstrate the changes in mass relative to the proportion of the starting mass, and hence make results comparable regardless of their starting size, volume or mass. It helps to standardise any variation in the quantity of plant tissue in the different samples. Learners now add any further changes they would make to the method in the third column of the table. Here, they can just note the change alongside the full method in the second column, rather than writing the whole method out again.
10 min	**Plenary** Discuss and agree on a final method, evaluating other learners' suggestions. Make sure learners are able to justify their decisions based on what they have learned about valid and reliable experiments, and the appropriateness of methods. You might need to provide prompts, such as asking if the choice is too time-consuming or involves unnecessary accuracy.

Lab lesson: Option 1 – run the experiment

Resources	• Worksheets B, C, D, E and F • Learners' completed Worksheet A • *Teacher walkthrough* video, *Teacher method, Teacher notes* • Equipment as listed in the *Teacher method*
Learning objectives	By the end of the lesson: • ***all*** learners should be able to follow a set of instructions • ***most*** learners should also be able to think about some of the strengths and weaknesses of the method they are undertaking compared to a planned method • ***some*** learners will be able to fully evaluate the method they are using as they go along, and suggest improvements.

Timings	Activity
15 min	**Starter/introduction** Give learners Worksheet B. Explain that they will use it to plan a method to investigate how the concentration of sucrose affects osmosis in a potato cylinder. They should use their answers to Worksheet A, and the discussions from the previous lesson to help them. You might need to explain that another way of preparing the potato sample is to use a cork borer to create a cylinder. This is an easy way of obtaining the same-sized pieces of potato; they need to trim the edges off to ensure each potato cylinder is the same length and to remove the skin.
10 min	**Main lesson** Now explain that they are going to be *given* a method to use. They will compare it to their planned method later on, so they should keep this in mind as they carry out the experiment; they should consider the strengths and weaknesses of both methods. Before learners begin the experiment, draw attention to safety when using a scalpel / sharp knife and cork borers. Also highlight the potential food allergies related to handling potato and sucrose solutions and, if required, supply learners with gloves. **Safety** You could provide the potato cylinders already prepared. Alternatively, the potato cylinders could already be cored and learners just have to trim them to size using scalpels, under supervision at a designated station in the room. However, freshly prepared cylinders work more efficiently. Circulate the classroom at all times during the experiment so that you can make sure that your learners are safe and that the data they are collecting is accurate.
20 min	Learners collect their equipment and set up their experiment following the diagram on Worksheet D and the method on Worksheet C. Learners record their data on Worksheet E.
10 min	Once the experiment has finished and all equipment has been cleared away, ask learners to look at Worksheet F to compare their planned method to the method they just carried out. Some learners will have been keeping notes as they went along, others might be considering this for the first time.
5 min	**Plenary** Evaluate the methods as a class. Which of the two methods was better? Why?

Teacher notes

Watch the *Teacher walkthrough* video and read these notes.

Each group will require:

- distilled water
- balance accurate to two decimal places
- sucrose solution (concentrations of: 20%, 40%, 60%, 80% and 100%)
- boiling tubes × 6
- rubber stoppers (to fit boiling tubes) × 6
- paper towels
- a potato
- a cork borer (if not available, learners should cut rectangles of size 5 mm × 5 mm × 60 mm)
- a smaller cork borer or pencil
- a white tile
- a scalpel / sharp knife
- a boiling tube rack
- a stopwatch (accurate to two decimal places)
- forceps
- a large beaker (for pouring waste sucrose solution into)
- measuring cylinder × 6 (or wash one cylinder between uses)

Safety

The information in the table overleaf is a summary of the key points you should consider before undertaking this experiment with your learners.

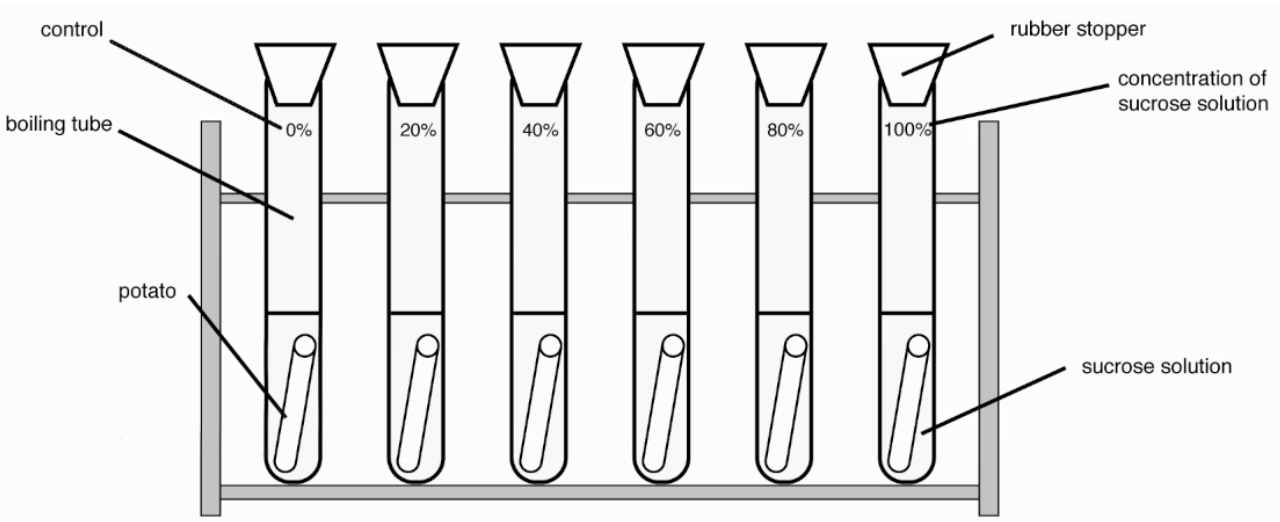
Some associated safety precautions include:

1. All scalpels should be counted out and in.
2. Demonstrate how to correctly use scalpels: fingers should be kept away from the blade, and all cutting should be done downwards away from the body, onto a white tile.
3. Show that cork borers should be used downwards onto a white tile and not into a potato that is held in the palm of the hand. Make sure learners are careful when removing the core, and that they use either a pencil or a smaller cork borer to do so.
4. Ask learners about any food allergies they might have. If contact with potato is an issue make sure they wear gloves when handling, assuming they have no allergies to latex. (Make sure you are aware of any latex allergies.)

It is your responsibility to carry out an appropriate risk assessment for this experiment.

Substance	Hazard	First aid
Sucrose	LOW HAZARD	**In the eye:** Flood the eye with gently-running tap water for at least 10 minutes. See a doctor if pain persists. **Swallowed:** Do no more than wash out the mouth with water. Do **not** induce vomiting. Sips of water may help cool the throat and help keep the airway open. See a doctor. **Spilt on the skin or clothing:** Brush solid off contaminated clothing. Rinse clothing or the skin as necessary. **Spilt on the floor, bench, etc.:** Brush up solid spills, trying to avoid raising dust, then wipe with a damp cloth. Wipe up solution spills with a cloth and rinse well.
Food	Allergies	Do not consume any foodstuffs in the lab. If discomfort persists see a doctor.
Sharps (e.g. scalpels, knives, cork borers, mounted needles, broken glassware)	Risk of cuts or puncture wounds due to sharps. Wounds can lead to infection, especially if the blade or point is contaminated.	**Minor cuts:** Rinse the wound with water. Get the casualty to apply a small, sterile dressing. **Severe cuts**: Lower the casualty to the floor. Raise the wound as high as possible. If feasible, ask the casualty to apply pressure on or as close to the cut as possible, using fingers, a pad of cloth or, better, a sterile dressing (adding further layers as necessary). If the casualty is unable to do so, apply pressure yourself, protecting your skin and clothes from contamination by blood if possible. Leave any embedded large bodies and press around them. Send for a first aider.
Latex gloves	Allergic reaction	Remove the gloves and wash hands under water. Look out for severe allergic reactions such as difficulty breathing and/or swelling of the face, body or tongue. Seek emergency medical attention immediately.

Experiment set-up



Teacher method

This is your version of the method that accompanies the *Teacher walkthrough* video.

Do not share this method with learners. Give them Worksheet C.

Before you begin
Plan how you will group your learners during the experiment session.

Think about:

- the number of groups you will need (group size 2–4 learners)
- the amount of equipment/chemicals required.

Experiment
Walk around the learners during the experiment in case they encounter any difficulties.

Step	Notes
1. Demonstrate how to correctly use the cork borer and scalpels / sharp knives.	*Count scalpels / sharp knives out and in.*
2. Learners should collect the equipment they need from the front of the class and use Worksheets C and D to help them set up.	
3. Learners should use a cork borer to cut 6 potato cylinders. This is done on a white tile. They should use a pencil or smaller borer to remove the potato.	*The cylinders need to be 5 cm in length, so the number of cylinders to be bored will depend on the size of the potato. For a large potato for example, 3 cylinders could each be cut in half to get the desired length. Remind learners of the safe way to use a cork borer.*
4. Learners use a scalpel to remove the skin from each end of the potato.	*Remind learners to keep fingers away from the scalpel / knife blade.*
5. Learners should cut each potato cylinder to 5 cm using a ruler and the scalpel.	*Consider if some learners would benefit from the cylinders already prepared.*
6. Learners should use a measuring cylinder to add 30 cm^3 of sucrose solution (20%, 40%, 60%, 80%, 100%) to the respective boiling tubes; and 100 cm^3 of distilled water. The tubes should be labelled with the concentrations at the top.	

Step	Notes
7. Learners should blot dry the potato cylinders with paper towels.	*Prompt learners as to why they are doing this step: it removes any surface water.*
8. Learners now measure the starting mass of each potato cylinder and record the results on Worksheet E. 9. Learners should add the correct potato cylinder to the correctly labelled boiling tube.	*Learners need to take care to remember which cylinder is going into which tube. Remind learners to make sure the potato is fully covered by solution; ask why this is important.*
10. Learners should start the stopwatch and leave the samples for 15 minutes.	
11. After the time has elapsed, learners remove each cylinder from the boiling tubes carefully using forceps and put them onto a paper towel. They then blot them dry them using the paper towel.	*Remind learners to put the cylinders on the paper towel in the order of the boiling tubes and be careful not to mix them up. They might find it helpful to use a marker to label the paper towel. Ask them why they are doing this step.*
12. Learners record the final mass of each potato cylinder.	
13. Learners then need to calculate the change in mass, and then the percentage change in mass. (The formula is given on Worksheet C.)	*Ask them why it's necessary to calculate the percentage change in mass. Make sure they know to state if the change is positive (an increase) or negative (a decrease).*

Clean-up

After the experiment learners should:

- rinse all glassware
- tidy up their work space
- ensure any spillages have been mopped up
- return all equipment and any unused solutions to you.

The distilled water and sucrose solution should be flushed down the sink with plenty of water.

Lab lesson: Option 2 – virtual experiment

Resources	• *Virtual experiment* video • Worksheets B, D, F and G • Stopwatch / timer per learner or group of learners

Learning objectives	By the end of the lesson: • ***all*** learners should be able to follow a set of instructions • ***most*** learners should also be able to think about some of the strengths and weaknesses of the method they are undertaking compared to a planned method • ***some*** learners will be able to fully evaluate the method they are using as they go along, and suggest improvements.

Timings	Activity
	Starter/introduction
10 min	Give learners Worksheet B. Explain that they will use it to plan a method to investigate how the concentration of sucrose affects osmosis in a potato cylinder. They should use their answers to Worksheet A, and the discussions from the previous lesson to help them. You might need to explain that another way of preparing the potato sample is to use a cork borer to create a cylinder. This is an easy way of obtaining the same-sized pieces of potato; they need to trim the edges off to ensure each potato cylinder is the same length.
	Main lesson
5 min	Now explain that they are going to watch someone else carry out the experiment. They will compare the method used in the video to their planned method later on, so they should keep this in mind as they watch the video; they should consider the strengths and weaknesses of both methods. You could give them Worksheet D, which is the experiment set-up.
10 min	Give learners Worksheet G and a stopwatch / timer each. Explain that this is a set of instructions that they have to follow throughout the lesson. Instruction 1 tells them to watch the video until it pauses on the equipment set-up. Start the video; it will automatically pause at the desired place. Click on the button in the top left to reveal a series of questions. Learners are told that they have 5 minutes to read the questions, then 5 minutes to think of some answers. They are not allowed to raise their hand to offer an answer until the full 10 minutes is up. At that time, they attempt to be the first learner to raise their hand to answer **one** of the questions.
10 min	Discuss and agree the answers as a class (see Worksheet G suggested answers for support). Learners then write the agreed answers on Worksheet G in their own words (instruction 2). Note, this is an opportunity for learners to compare the method to their planned method. Use the suggested answers to help guide the discussions in the right direction if needed. For example, ensure learners know that the incubation time of 15 minutes is a compromise between seeing results and wasting time.
15 min	Resume play on the video; it will automatically pause before the results are revealed. They will see the experiment being carried out; Instruction 3 of Worksheet G tells them to note down any differences between the method being shown and their planned method. (Some learners might need additional sheets of paper for this.) *Continues on next page …*

Timings	Activity
5 min	**Main lesson continued …** The final instruction (instruction 4) asks learners to calculate the change in percentage mass of each sample. Remind learners about including whether the change in mass was an increase (positive percentage change) or decrease (negative percentage change). Resume play to reveal the completed table; learners can compare their answers to those in the table on screen. The video will pause at this point because the rest of the video discusses the results, which will be covered in detail in the *Debriefing lesson*. Ask learners to look at Worksheet F to compare their planned method to the method they just watching being carried out. They should be able to do this fairly quickly if they made notes as per Instruction 3 on Worksheet G.
5 min	**Plenary** Evaluate the methods as a class. Which of the two methods was better? Why?

Debriefing lesson: Interpreting observations and data

Resources

- Learners' completed Worksheets C, E, F and G
- Worksheets H, I and J
- Graph paper
- *Virtual experiment* video

Learning objectives

By the end of the lesson:

- ***all*** learners should be able to summarise their results
- ***most*** learners should be able to interpret results from a graph including what the concentration inside the potato cells is relative to the sucrose solution
- ***some*** learners will be able to evaluate the quality of their results.

Timings	Activity
5 min	**Starter/introduction** Consolidate the skills of the previous lessons using the matching activity on Worksheet H. Discuss the answers and resolve any misconceptions.
10 min	**Main lesson** Make sure learners understand that interpreting results is the process of explaining the data that has been collected using their scientific knowledge. Discuss what can be done with raw data to make it more meaningful, easier to understand and therefore easier to interpret. Ideas should include calculating mean values and plotting graphs. For each of these, discuss the advantages and disadvantages. Remind them that they have already decided to interpret their results using the percentage change in mass rather than just the change in mass. If necessary, revise why this is a more accurate approach.
15 min	Ask learners to plot a graph of their results using Worksheet I for support. An exemplar graph has been provided in the suggested answers section if you need it.
10 min	They now need to interpret and analyse the results from their graph (steps 1 and 2), using Worksheet J. Some learners might also have time to evaluate their data (step 3); it is expected that abler learners will get to this point. For learners taking the Extended course, ask them to include key words such as 'flaccid', 'turgid', 'isotonic' and 'plasmolysed'. For Step 1, less able learners might benefit from the following gap-filling exercise; answers in orange (values are from the *Virtual experiment* video). As the [concentration of sucrose] increases, the mass of the potato samples [decreases]. In the 0% sucrose solution, the potato had a percentage increase in mass of [6]%; at [100]% sucrose solution, the potato cylinder had a percentage decrease in mass of [20]%. At 0% sucrose solution the mass of the potato cylinder [increased]. As the sucrose concentration increases from 0%, the percentage change in mass is still an increase in mass but the extent of the increase decreases, until [10]% sucrose solution, where the mass of the potato does not change. As the sucrose concentration increases from [10]%, the percentage change in mass of the potato core becomes [negative] and the percentage decrease increases. This means the potato is losing more percentage mass as the concentration of sucrose [increases]. This continues up to a point, around [40]% sucrose. After this point, the percentage change in mass is still a decrease but the rate of decrease slows down as the concentration increases. *Continues on next page …*

Timings	Activity
	Main lesson continued …
5 min	Arrange learners into groups that are different from those they have worked in previously. Ask them to swap and peer review each other's work. What do they think of the conclusions that their partner has made, are they reasonable? Did they come to the same conclusion? Do they need to make amends to their conclusion and evaluations? Can they relate any different interpretations to the accuracy of the method used?
10 min	As a class, discuss some of the possible answers to Worksheet J (use the sample answers if required). You might also like to watch the end of the *Virtual experiment* video (from 4:09 to the end), which discusses the results obtained. Make sure any misconceptions are resolved.
	Plenary
5 min	Ask learners to quickly review their answers to questions on Worksheet C/G and then to use what they've learned to discuss how they might plan an experiment to investigate the effect of different salt concentrations on osmosis in plant tissue.

Worksheets and suggested answers

	Worksheets	Suggested answers
For use in the *Briefing lesson:*		
A: Choosing a method	**19**	**39**
For use in *Lab lesson: Option 1:*		
B: Planning your method	**20–21**	**40**
C: Method	**22–24**	**42**
D: Equipment set-up	**25**	**—**
E: Results	**26**	**—**
F: Comparing methods	**27–28**	**43**
For use in *Lab lesson: Option 2:*		
B: Planning your method	**20–21**	**40**
D: Equipment set-up	**25**	**—**
F: Comparing methods	**27–28**	**43**
G: Following instructions	**29–32**	**44**
For use in the *Debriefing lesson:*		
H: Definitions match up	**33**	**46**
I: Plotting a graph	**34**	**47**
J: Interpreting the results	**35–38**	**48**

Worksheet A: Choosing a method

Note down any weaknesses of the method in column 1 under each step. Write an improved method in the **Improvements 1** column. You can add in new steps as well as amending existing steps. Add any final improvements to the **Improvements 2** column.

	Improvements 1	**Improvements 2**
1. Cut a piece of potato that is 1 cm × 1 cm × 1cm (volume 1 cm^3). Cut a piece of carrot that is the same volume.		
2. Put the potato and carrot piece into a separate test-tube of tap water.		
3. Leave for 10 minutes.		
4. Measure the mass of each sample.		

Worksheet B: Planning your method

Circle each choice to plan your method. Make sure you can justify your choices.

My samples will be a: 10 cm-long cylinder 5 cm-long cylinder 2 cm^3 cube

Because: ……………………………………………………………………………………………………..

I will measure the change in: volume mass

Because: ……………………………………………………………………………………………………..

If measuring the mass, I will use a balance with the following degree of accuracy:

1 decimal place 2 decimal places 3 decimal places

Because: ……………………………………………………………………………………………………..

If measuring the volume, I will do this by……………………………………………………………….....

Because: ……………………………………………………………………………………………………..

I will put the samples in a: test-tube boiling tube 100 cm^3 beaker

Because: ……………………………………………………………………………………………………..

The following are possible sets of sucrose concentrations that could be used.

A: 0%, 2%, 4%, 5%, 6%, 8%

B: 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 100%

C: 0%, 50%, 100%

D: 0%, 20%, 40%, 60%, 80%, 100%

E: 0%, 10%, 50%, 90%, 100%

F: my own ……………………………………………………………………………………………………..

I will use set ….. **because** ……………………………………………………………………………...

I will incubate the potato in the sucrose solutions for: 1 minute 15 minutes 1 hour

Because: ……………………………………………………………………………………………………..

Using your answers to Worksheet A, write a step-by-step method for this experiment.

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Worksheet C: Method

Follow the step-by-step instructions to carry out the experiment. Think about the questions in the grey panels as you go along. You will have time to write down your answers during **step 11**.

1. Collect the equipment and set it up using Worksheet D to help you.

2. Use the cork borer to cut a cylinder of potato. Make sure you do this on a white tile.

> *Do not hold the potato in your hand whilst using the cork borer as you could slip and cut your hand.*

3. Use a scalpel to remove the peel from each end. Use a ruler and the scalpel to cut the cylinder so it is 5 cm long. Repeat until you have 6 samples.

> *Take care when using the scalpel; always cut away from the body onto a white tile. Do not put fingers near the blade.*

4. Measure out 30 cm^3 of 0% sucrose solution (distilled water) into a boiling tube and label. Add the label to the top of the boiling tube. Put into a boiling tube rack.

5. Repeat for 20%, 40%, 60%, 80% and 100% sucrose solutions, so you have 6 boiling tubes.

6. Use a paper towel to gently blot each sample.

> *What do you see on the paper towel?*

7. Measure the mass of the first potato cylinder using a balance; record the mass to 2 decimal places. Use forceps to handle the potato cylinder. Record your measurements on Worksheet E.

8. Place the potato cylinder into the 0% sucrose solution. Place a rubber stopper in the top of the boiling tube.

9. Make sure the potato cylinder is completely covered by the liquid in the boiling tube.

10. Repeat steps 7, 8 and 9 with the rest of the potato cylinders, placing each one into a different boiling tube according to the different sucrose solutions.

> *Make sure you put each potato cylinder into the correct boiling tube, so that you have correctly recorded the mass of the potato in each tube.*

11. Using a stopwatch, leave the potato samples for 15 minutes. During this time, answer the questions at the end of the method (after step 16). Then return to **step 12** once the timer beeps.

12. After 15 minutes, remove the 0% potato cylinder carefully using forceps. You might need to pour the solution out carefully into an empty beaker first, so that you can get to the potato.

13. Blot the potato cylinder using a paper towel, as before.

14. Record the final mass of the potato cylinder to two decimal places. Record the mass on Worksheet E.

15. Repeat steps 12, 13 and 14 with the remaining potato cylinders. Take care not to mix up the samples as you do this.

16. For each sample, use the formula below to calculate the percentage change in mass.

$$\textbf{percentage change in mass} = \frac{\textbf{difference between final mass and initial mass}}{\textbf{initial mass of potato}} \times \textbf{100}$$

Questions about the method – answer these during the 15 minute incubation period.

(a) Why has a cylinder have been used rather than a cube or a slice of potato?

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(b) Why is it important that each potato cylinder is the same length?

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(c) Why do you need to use the same volume of each solution?

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(d) Why is it important to blot each sample before measuring their mass?
Hint: think about what you saw on the paper towel.

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(e) What do you think the rubber stopper is used for? Hint: water evaporates.

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(f) Why is it important for the potato to be completely covered by the solution?

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(g) Why are the samples left for 15 minutes and not overnight?

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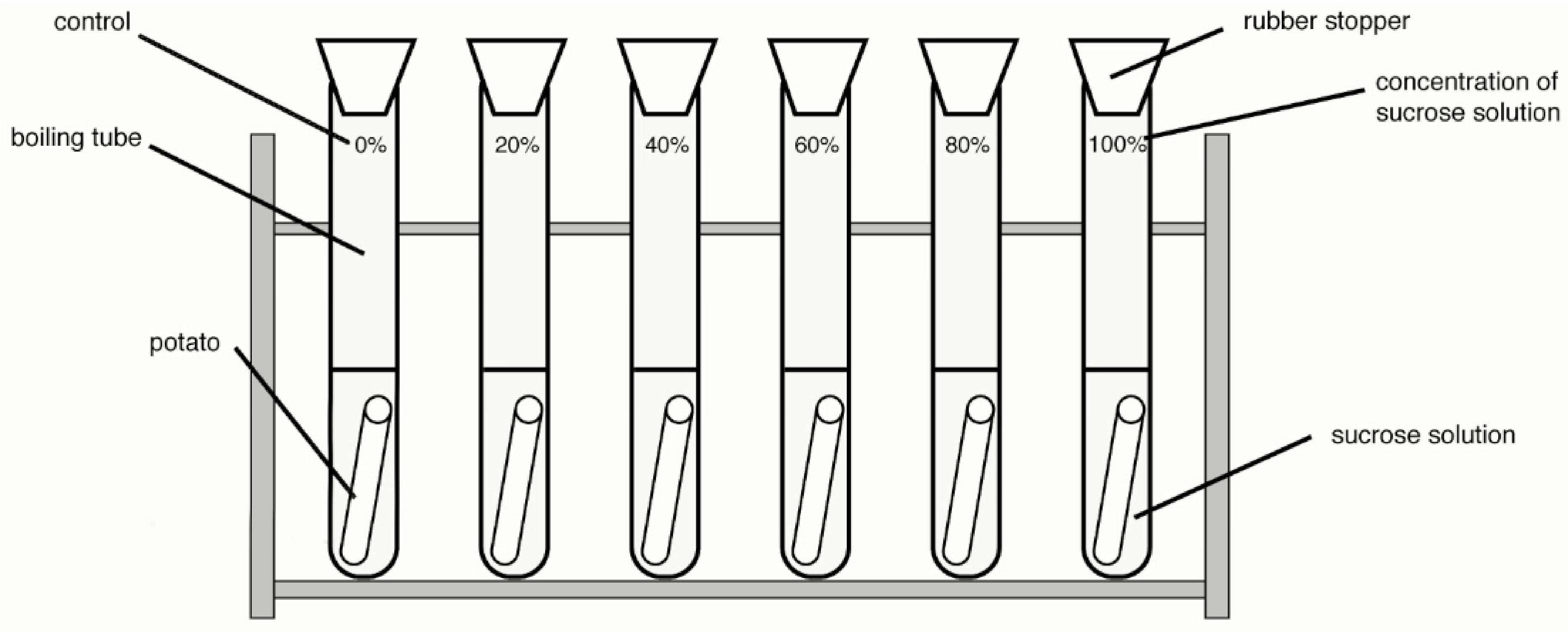
Worksheet D: Equipment set-up



Worksheet E: Results

Record your measurements in the table below.

Percentage sucrose solution (%)	Initial mass / g	Final mass / g	Change in mass / g	Percentage change in mass (%)
0				
20				
40				
60				
80				
100				

You can use the space below to write your working for the percentage calculations.

Worksheet F: Comparing methods

For each factor, list your planned method and the actual method followed. Explain the strength and weakness of each method.

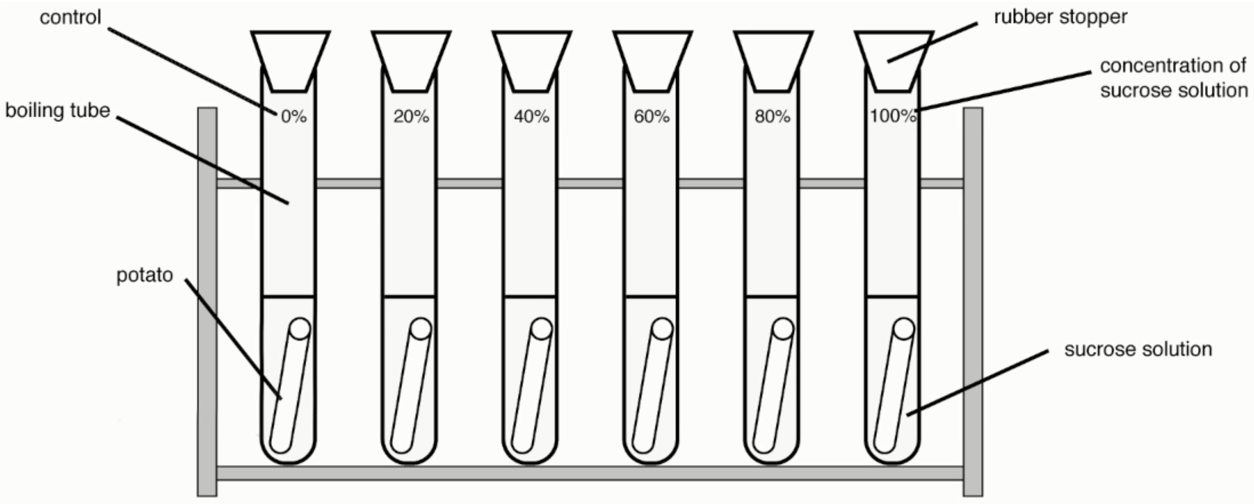
Factor	Planned	Actual	Strength / weakness of each method
Form of potato			
Mass or volume measured			
Container used			
Use of stopper			
Sucrose concentrations			
Accuracy of balance			
Time in solution			

Use the blank table on the next page to for any other items you can think of.

Factor	Planned	Actual	Strength / weakness of each method

Worksheet G: Following instructions

Instruction 1: Watch the video until it pauses on the equipment set-up shown below.



When the video pauses, your teacher will reveal a series of questions on screen.

You have **5 minutes** to read the questions, then **5 minutes** to think of your answers.

You must **not** put your hand up with answers until the full **10 minutes** have passed.

Once the 10 minutes has passed, raise your hand to answer **one** of the questions. You can use a timer to help you keep track of time.

Instruction 2: The questions from the video are repeated below. Following the class discussion about the answers, write down the correct answer to each question in your own words.

1. Why has a cylinder been used rather than a cube or a slice of potato?

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2. Why is it important for each potato cylinder to be the same length?

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3. Why is the same volume of each solution used?

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4. Why is it important to blot each sample before measuring their mass?

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5. Why is it important to prevent evaporation from the boiling tubes?

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6. Why is it important for each potato cylinder to be fully covered by the solution?

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7. Why are the samples left for 15 minutes and not overnight?

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Instruction 3: Continue watching the video. As you do, make a note of any differences between the method shown and your planned method. Consider the strengths and weaknesses of these differences.

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Instruction 4: The results from the experiment in the video are included in the table below. Use the formula to calculate the percentage change in mass for each sample. You can use the space below the table to write your working for any calculations.

Percentage sucrose solution (%)	Initial mass / g	Final mass / g	Change in mass / g	Percentage change in mass (%)
0	1.37	1.45		
20	1.43	1.35		
40	1.37	1.18		
60	1.41	1.12		
80	1.31	1.17		
100	1.34	1.05		

$$\textbf{percentage change in mass} = \frac{\textbf{difference between final mass and initial mass}}{\textbf{initial mass of potato}} \times 100$$

Worksheet H: Definitions match up

Match the correct definition to each key word.

Key word	Definition
Valid	Detailed examination of the results. Includes processing results to see a pattern, including drawing graphs. The pattern is described and explained using scientific theory by interpreting the results.
Evaluation	Detailed descriptions of what can be seen, heard and felt during an experiment.
Independent variable	The process of judging the validity of an experiment based on its method and/or data. Suggestions of how to improve accuracy are provided and explained.
Analysis	Differences between what should be observed/recorded and what is actually observed/recorded that are caused by the technique or equipment used rather than the independent variable.
Observations	How close a measured value is to the exact/true value. Choice of equipment and techniques used will affect this.
Interpreting	Whether or not the results can be repeated to a similar standard to obtain more or less the same result. Normally we repeat an experiment at least 3 times to look at this.
Reliability	An experiment in which only one variable is changed and the results are considered trustworthy.
Sources of error	Descriptive observations are used to explain how two sets of data differ.
Accuracy	Where the results are given meaning. The pattern of the results is explained using scientific theory. The observations are attempted to be understood.
Qualitative comparison	Numbers and measurements are used to describe how two sets of data differ.
Quantitative comparison	The single variable that is changed in an experiment; this relates directly to the factor you are investigating.

Worksheet I: Plotting a graph

When plotting graphs, there are **six** key things to remember. Use each panel as a checklist.

1. AXES ☐	2. LABELS AND UNITS ☐
The **independent variable** is plotted along the ***x*-axis** (horizontal axis). The **dependent variable** is plotted along the ***y*-axis** (vertical axis). Since the independent variable is the one we control, it makes it easier to interpret the results if this is plotted on the *x*-axis. The analysis of the graph can then start with, for example 'As the (independent variable) increases, the (dependent variable) …	Don't forget to label both axes, including units. This makes it easier to interpret the graph as you do not need to look back at your results table.
3. SCALE ☐	**4. PLOTTING POINTS** ☐
This needs to be linear, which means the scale goes up evenly. For example, every 10 squares on the graph paper represents 2 g. If the scale was not linear a curved graph could appear as a straight line and this would affect the analysis.	Plot points carefully using a sharp pencil and draw an x to mark the point. This makes it easier to see where the line of best fit should go. It can help to go along the *x*-axis first, and then up along the *y*-axis.
5. LINE OF BEST FIT ☐	**6. KEY** ☐
This is a line that goes through (or closely to) as many points as possible. This should be a single line and can be straight or curved. This line represents the overall pattern/trend of the results.	Sometimes symbols or colours will be used on a graph for two or more sets of data. A key helps to explain what each colour or symbol means.

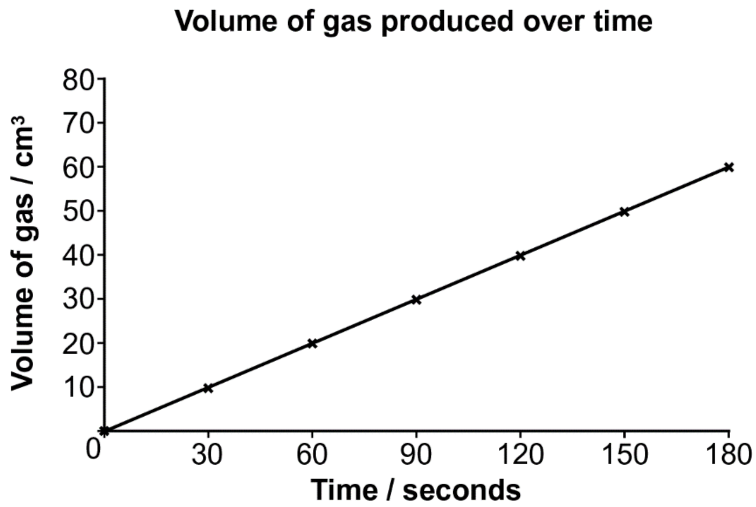
Worksheet J: Interpreting the results

STEP 1: Analyse the graph

Consider each of the following points when analysing a graph. Tick each point after you have included the relevant information in your analysis.

1. What does the line of best fit look like? Is it a straight line or a curve? ☐
2. If it is a curve, how does it change? ☐
3. Remember to always use your labels when analysing the graph. ☐
4. Describe how the results change along the *x*-axis and then along the *y*-axis; this summarises the relationship between the independent and dependent variables. ☐
5. Then use data points from the graph to illustrate the proposed relationship. For example, what does time increase from and to; what is the starting and final volume; is there a simple link, e.g. as time doubles does the volume also double? ☐

<u>Example analysis of a graph:</u>



As the time increases, the volume of gas increases.

Describes how the *x*-axis is changing. Describes how the *y*-axis is changing.

As time increases, the volume of gas increases. When time is 0 seconds, the volume is 0 cm^3. This increases to 60cm^3 at 180 seconds. As the time doubles, the volume of gas doubles. The volume increases by 10 cm^3 every 30 seconds.

Uses points from the graph to illustrate.

<u>Analysis of your graph</u>

Use the example analysis above to write an analysis of your own graph.

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STEP 2: Interpret the graph

This is where you need to explain what is happening on your graph.

There are three key areas on the osmosis graph:

1. where the line of best fit is above the *x*-axis
2. where the line crosses the *x*-axis and
3. where the line is below the *x*-axis.

To interpret each of these areas, we need to use the scientific theory of osmosis. We know that water moves into and out of the cell by osmosis. Water has mass, so it follows that an increase in mass of the potato cylinder suggests that water has moved into the cell, whereas a decrease in mass suggests that water has moved out of the cell.

Complete the table. Use this to help you write up your findings as three short paragraphs.

Observation	Mass has increased / decreased / stayed same	Water has moved in / out / no net movement	Does the cell have a higher/lower/the same water concentration compared to the sucrose solution?
At 0% the line of best fit is above the *x*-axis.			
At ……..the line of best fit crosses the *x*-axis.			
At ……. the line of best fit is below the *x*-axis.			

Write up

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STEP 3: Evaluation of data

Look at your data to determine if there are errors and where they might have been introduced.

Question	Answer	Explanation
How close were your points to the line of best fit?		
Were there any anomalies?		
Can you assess the reliability of your results?		
Do you know of any sources of error in your experiment?		

Explain how you could improve the experiment in order to improve the quality of your data.

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Worksheet A: Suggested answers

Learners' should provide their own suggestions. Possible weaknesses of the method might include:

- It is difficult to accurately cut the potato and carrot into cubes with exactly the same volume.
- A carrot has a core and if the cube includes this it could affect the result; cutting a cube of carrot without including the core is fiddly and time-consuming.
- Test-tubes are small and fitting a cube in is difficult.
- The cubes are very small so will they show enough of a difference (a measurable difference).
- Tap water has been used; its contents might vary between the test-tubes.
- Volume of tap water has not been measured and this should be a controlled variable.
- 10 minutes might not be long enough to see a result; any change during that time might not be sufficiently measurable, especially as the cubes are so small.
- Mass of cube not measured beforehand so can't possibly we know if the mass has changed.
- The cubes were not dried before measuring, so the measurement is inaccurate as it includes surface water from the outside of the cube.
- The experiment was only done once, i.e. there were no repeats.

Learners' should provide their own suggestions. Possible improvements to the method might include the following:

- Use a cork borer and ruler to generate the samples so that each one has the same volume.
- Use a bigger cube so there is the potential for a bigger change and this can be measured more easily.
- Use a boiling tube or a beaker to allow a bigger cube to be used.
- Use distilled water so that it is the same between each test.
- Leave for a longer time, possibly as long as 24 hours, to allow more time for osmosis to occur so the change is bigger and easier to measure.
- Measure the mass beforehand so that you can compare and calculate change in mass.
- Dry the cubes before measuring each time to remove any surface water from the outside.
- Repeat the experiment.

Worksheet B: Suggested answers

Any decision by a learner is valid so long as they can justify their choices in the context of the experiment. Possible justifications for each choice are as follows.

How to sample potato …
Cylinders are more accurate, can use ruler to measure length and know the volume is consistent.

10 cm-long cylinder: bigger cylinder allows for large change in mass, which is easier to measure.

5 cm-long cylinder: allows for measureable change in mass but easier to generate and can get more repeats from one potato. Also requires less water in the test-tube.

2 cm^3 cube: can get more samples from one potato.

Way of measuring change …
volume: not affected by surface water on the outside.

mass: less time-consuming than measuring volume and less room for error to be introduced; you don't need to start with exactly the same volume each time so it is easier and quicker to set up.

Degree of accuracy for measuring mass …
1 decimal place: allows enough degree of accuracy to see a change and suitable balances are easily available.

2 decimal places: more precise, so can more accurately measure a change; still relatively easy to source suitable balance.

3 decimal places: very precise, allows easier differentiation, easier to measure the difference.

Ways of measuring volume …
With a ruler, and ensure all sides are 2 cm^3.

With a eureka can (density can) and 10 cm^3 measuring cylinder (however the small volume involved would require an appropriately sized eureka can).

Container …

test-tube: easily available, requires only a small volume of water.

boiling tube: potato fits in easier and can use larger samples that might be better for a measurable change.

100 cm^3 beaker: less need for covering as more volume of water used, could potentially fit repeats into same beaker, easier to get potato in and out.

Set of sucrose concentrations …
Learner should identify that:
A: that this is very limited range, especially when compared to the other options

B: this is a comprehensive range, would give a lot of data

C: this covers key points (0, 50 and 100%)

D: this allows for total range to be covered 0-100% but also enough points in between so that if one result is inaccurate it will be more obvious; not as time consuming as B; more evenly-spaced than E.

E: this has total range but also fills in gaps in between.

The more concentrations used, the more time-consuming the experiment.

Time for incubation in liquids …
1 minute: allows for repeats to be done quickly but might not be sufficiently long to see a measurable change.

15 minutes: gives long enough for a measurable change and the trend to be deduced but not too time-consuming.

1 hour: gives more time for osmosis to happen and therefore to allow a bigger difference between the different solutions to be recorded (more measurable change) but doesn't allow time for repeats if done in a lesson.

Learners' methods should show evidence of, or understanding of, the following:

Understanding that the aim of the experiment: to explore if there is a change in mass / volume and how this would be achieved.

Compromise between precision and time: for example, using eureka cans to measure volume would give an accurate result but would be fiddly and time-consuming; does measuring mass to an accuracy of 3 decimal places for mass really add any necessary extra detail?; would it add anything meaningful to the results?

Choosing a range: learners should understand that 0% and 100%, the extremes available, are vital and that selecting the values in between depends on the aim of the experiment and the time available. Some learners might even suggest doing the experiment once using a large range with lots of in-between concentrations to find a concentration where the mass does not change, and then use this data to focus more on solutions closer to this value instead of evenly-spacing the concentrations used.

Knowledge of the need for techniques that allow valid data collection: for example, only changing one variable (the independent variable), keeping other variables constant

Worksheet C: Suggested answers

Possible answers to the questions within the method.

(a) Why has a cylinder been used instead of a cube or slice of potato?

It is easier to cut samples of the same size when using a cork borer, which generates cylinders. All cylinders made will have the same diameter, then you just need to use a ruler to measure the same length, and then all pieces of potato will have the same dimensions.

(b) Why is it important that each potato cylinder is the same length?

For valid data to be collected and compared, each sample must have the same surface area for water to enter / leave the potato.

(c) Why do you need to use the same volume of each sucrose solution?

For valid data to be collected and compared, all other variables, including volume of solutions should be kept constant, so that the only variable being changed is the concentration of the solution.

(d) Why is it important to blot each sample before measuring their mass? Hint: look at the paper towel, what can you see?

There is moisture / damp / water on the paper towel. The process of blotting removes excess surface water. This is water that is on the outside of the potato, rather than inside the cells, and so should not be included when measuring the mass of the potato; it would invalidate the results.

(e) What do you think the rubber stopper is used for? Hint: water evaporates.

The rubber stopper prevents water evaporating from the solution and changing the sucrose concentration.

(f) Why is it important for the potato to be completely covered by the solution?

So that osmosis can occur across the full surface area; if some samples were not completely covered, then each sample would have different surface areas exposed to the solution and the results would not be valid.

(g) Why are the samples left for 15 minutes and not overnight?

15 minutes should be enough time for a measurable change in mass to occur. This is enough time for repeats to be done and for a trend to be identified within a reasonable timeframe.

Worksheet F: Suggested answers

Below are some possible answers that learners might suggest. As long as they have explained their answers, there are many valid suggestions.

Factor	Planned	Actual	Strength / weakness of each method
Form of potato	10 cm cylinder	5 cm cylinder	5 cm cylinder is quicker and easier to achieve from a potato and you get more per potato, however, 10 cm would show a bigger change in mass. The 5 cm cylinder will still give a measureable change in mass.
Mass or volume measured	volume	mass	Measuring volume is more difficult to do accurately and is more time-consuming. Allows more room for error. When measuring mass, you have to blot the samples and you could mix up the samples.
Container used	test-tube	boiling tube	Potato core fits more easily into the boiling tube so will be easier to put in and remove. Both are easily available in a lab.
Use of stopper	no	yes	Prevents evaporation of water from the sucrose solution which could change the concentration of the solution, however this might not realistically be necessary given the samples are only incubated for 15 minutes.
Sucrose concentrations	10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 100%	0%, 20%, 40%, 60%, 80%, 100%	The planned did not include minimum concentration possible at 0%, however, does allow for more data points and a more reliable line of best fit.
Accuracy of balance	3 dp	2 dp	3 dp is more precise but balances with this degree of accuracy are more difficult to source; 2 dp is sufficiently accurate to measure a difference between samples.
Time in solution	1 hour	15 minutes	1 hour would be better as it would allow a bigger change to be recorded, however, it would take longer to repeat and so not realistic within a lesson; 15 minutes still allows the basic trend to be recorded.

Worksheet G: Suggested answers

Instruction 2. Possible answers to the questions within the method.

1. Why has a cylinder been used instead of a cube or slice of potato?

   It is easier to cut samples of the same size when using a cork borer, which generates cylinders. All cylinders made will have the same diameter, then you just need to use a ruler to measure the same length, and then all pieces of potato will have the same dimensions.

2. Why is it important that each potato cylinder is the same length?

   For valid data to be collected and compared, each sample must have the same surface area for water to enter / leave the potato.

3. Why do you need to use the same volume of each sucrose solution?

   For valid data to be collected and compared, all other variables, including volume of solutions should be kept constant, so that the only variable being changed is the concentration of the solution.

4. Why is it important to blot each sample before measuring their mass? Hint: look at the paper towel, what can you see?

   There is moisture / damp / water on the paper towel. The process of blotting removes excess surface water. This is water that is on the outside of the potato, rather than inside the cells, and so should not be included when measuring the mass of the potato; it would invalidate the results.

5. Why is it important to prevent evaporation from the boiling tubes?

   If water evaporated from the sucrose solutions it would change the sucrose concentration, so the independent variable would not be controlled (you would not know what the concentration of the solutions were) and the results would not be valid.

6. Why is it important for the potato to be completely covered by the solution?

   So that osmosis can occur across the full surface area; if some samples were not completely covered, then each sample would have different surface areas exposed to the solution and the results would not be valid.

7. Why are the samples left for 15 minutes and not overnight?

   15 minutes should be enough time for a measurable change in mass to occur. This is enough time for repeats to be done and for a trend to be identified within a reasonable timeframe.

Instruction 3. Learners make their own notes on possible strengths and weaknesses. Some possible examples are given in the suggested answers for Worksheet F.

Instruction 4:

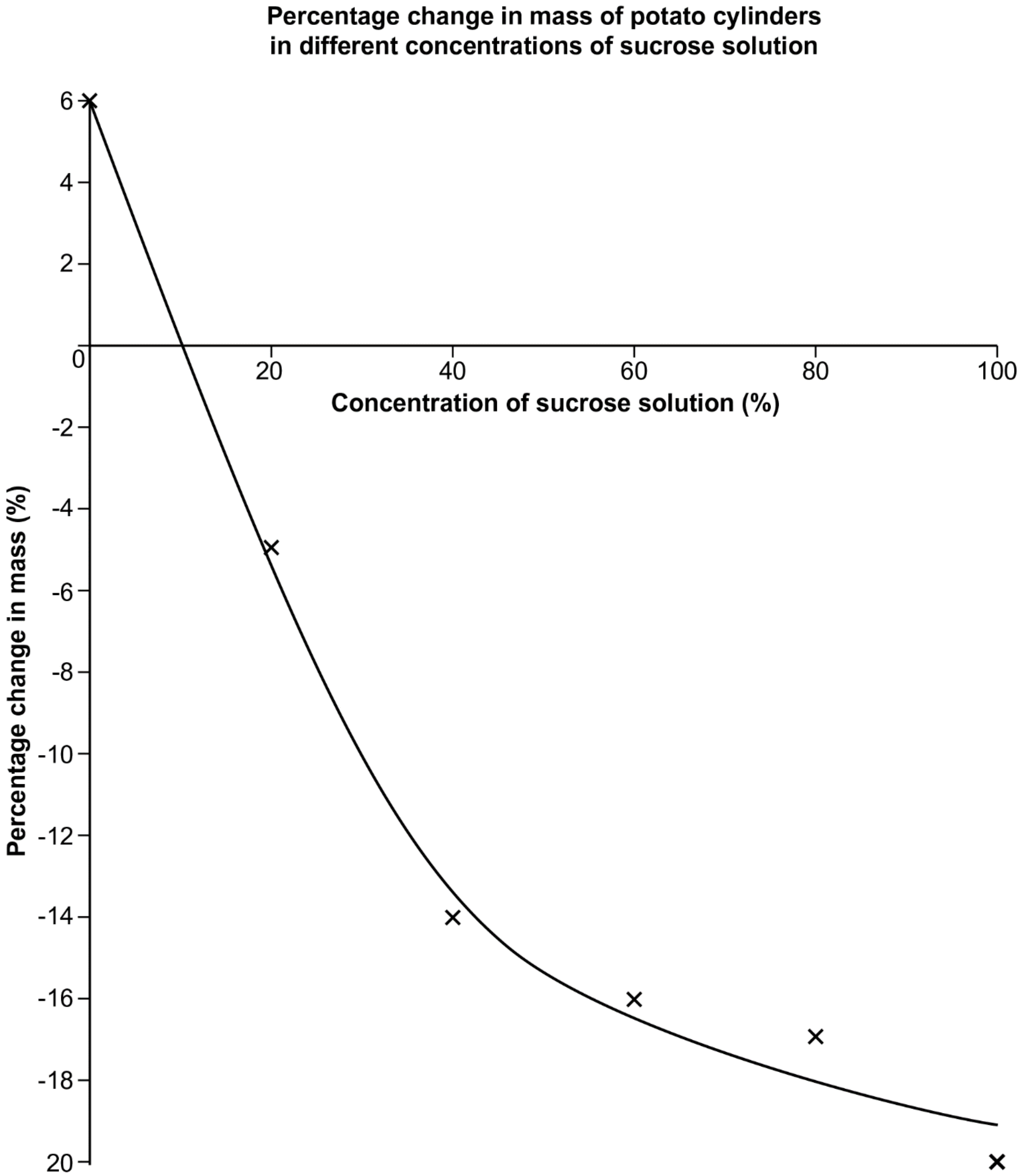
Percentage sucrose solution (%)	Initial mass / g	Final mass / g	Change in mass / g	Percentage change in mass to 1 sf (%)
0	1.37	1.45	0.08	+ 6
20	1.43	1.36	0.07	– 5
40	1.37	1.18	0.19	– 14
60	1.41	1.18	0.23	– 16
80	1.31	1.09	0.22	– 17
100	1.34	1.07	0.27	– 20

Worksheet H: Answers

Key word	Definition
Valid	An experiment in which only one variable is changed and the results are considered trustworthy.
Evaluation	The process of judging the validity of an experiment based on its method and/or data. Suggestions of how to improve accuracy are provided and explained.
Independent variable	The single variable that is changed in an experiment; this relates directly to the factor you are investigating.
Analysis	A detailed examination of the results of an experiment. This can include processing results to reveal a pattern, including drawing graphs. The pattern is then described and explained using scientific theory by interpreting the results.
Observations	Detailed descriptions of what can be seen, heard and felt during an experiment.
Interpreting	Where the results are given meaning. The pattern of the results is explained using scientific theory. The observations are attempted to be understood.
Reliability	Whether or not the results can be repeated to a similar standard to obtain more or less the same result. Normally we repeat an experiment at least 3 times to look at this.
Sources of error	Differences between what should be observed / recorded and what is actually observed / recorded that are caused by the technique or equipment used rather than the independent variable.
Accuracy	How close a measured value is to the exact / true value. Choice of equipment and techniques used will affect this.
Qualitative comparison	Descriptive observations are used to explain how two sets of data differ.
Quantitative comparison	Numbers and measurements are used to describe how two sets of data differ.

Worksheet I: Suggested answers

This **exemplar** graph has been drawn using the results obtained from the *Virtual experiment* video.



Worksheet J: Suggested answers

Step 1

Learners' own analysis of their graph. It should follow a similar structure/approach to the gap-filling exercise in the lesson plan. Below is an exemplar answer.

As the concentration of sucrose increases, the mass of the potato samples decreases. In the 0% sucrose solution, the potato had a percentage increase in mass of 6%; at 100% sucrose solution, the potato cylinder had a percentage decrease in mass of 20%. At 0% sucrose solution the mass of the potato cylinder increased. As the sucrose concentration increases from 0%, the percentage change in mass is still an increase in mass but the extent of the increase decreases, until 10% sucrose solution, where the mass of the potato does not change. As the sucrose concentration increases from 10%, the percentage change in mass of the potato core becomes negative and the percentage decrease increases. This means the potato is losing more percentage mass as the concentration of sucrose increases. This continues up to a point, around 40% sucrose. After this point, the percentage change in mass is still a decrease but the rate of decrease slows down as the concentration increases.

Note that the sucrose concentration where the line of best fit crosses the x-axis is usually somewhere between 10–30% sucrose concentration.

Step 2

Observation	Mass has increased / decreased / stayed same	Water has moved in / out / no net movement	Does the cell have a higher/lower/the same water concentration compared to the sucrose solution?
At 0% the line of best fit is above the *x*-axis.	increased	water has moved in to the cell	The cell has a lower water concentration than the sucrose solution.
At **10%** the line of best fit crosses the *x*-axis.	stayed the same	water moved in and out at the same rate	The cell has the same water concentration as the sucrose solution.
At **15%** the line of best fit is below the *x*-axis.	decreased	water has moved out of the cell	The cell has a higher water concentration than the sucrose solution.

Learners' own interpretation of their graph. Below is an exemplar answer. **Bold** highlighting indicates Extended level content.

Osmosis is the net movement of water molecules from a region of their higher concentration (dilute solution) to a region of their lower concentration (concentrated solution) down a concentration gradient through a partially permeable membrane.

In 0% sucrose solution there is a higher water concentration outside the cell, ***it has a higher water potential than inside the cells****. This causes water to move from the higher concentration outside the cell to the lower concentration inside the cell by osmosis. The partially permeable membrane is the cell membrane of the potato cells. This gain in water causes the potato to gain mass.* ***The cells become turgid and the water pushes the cell membrane against the wall causing turgor pressure, this keeps plants upright.***

In 10% sucrose solution, the water concentration outside the cell is the same as the water concentration inside the cell. This means there is no net movement of water so the cell remains the same mass. ***We call this the isotonic concentration.***

At 50% sucrose solution, there is a lower water concentration outside the cell, ***it has a lower water potential than inside the cells****. This causes water to move from the higher concentration inside the cell to the lower concentration outside the cell by osmosis. This loss of water causes the potato to lose mass.* ***The cells first become flaccid as the cytoplasm no longer pushes the cell membrane against the cell wall. Eventually the cells lose so much water that they become plasmolysed. The cell membrane pulls away from the cell wall.*** *In concentrations over 40% sucrose, the percentage change in mass is still a decrease but the rate of decrease slows down as the concentration increases. This is because there is a limit to how much water the potato cells can lose and so the change in mass slows down even if the concentration of sucrose increases.*

Step 3

Learners' own responses. Possible explanations of why they can / can't assess the reliability of their results might include:

The experiment was only done once. A reliable experiment is one that would lead to the same / very similar result each time. Based on one set of results we cannot assess that. Students could suggest pooling results and calculating an average but should recognise that there could still be variations in the method between groups which could lead to error.

Possible sources of error might include:

- Used a two decimal place balance; a three decimal place balance would give more precision but are more expensive to source.
- The potato cylinders did not spend exactly the same amount of time in solution as each other as it is tricky to ensure they all have exactly 15 minutes; this is particularly a problem when samples were removed and their mass taken before the next sample was removed from the boiling tube (they should all be removed at the same time). This could affect the accuracy of the

results. Leaving the cells for a longer period of time, e.g. overnight, reduces the impact of an extra minute in solution but does mean the experiment takes much longer to perform.

- The practical was only repeated once, so it is not possible to assess the reliability of the results unless we collect results from other groups and calculate a mean.
- Sources of error could include reaction time with the stopwatch, especially if someone is doing more than one thing at once; working in pairs or groups can minimise this risk.
- It is difficult to ensure some of the potato cylinders are completely covered by the solution; attaching some form of weight to each sample would help (e.g. a pin).
- Human error could have occurred, e.g. mixing up the potato cylinders after measuring; having a partner/group member double-check what you are doing would help minimise risk.

Learners' own suggestions for improvement should be justified.

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