Cambridge Assessment International Education

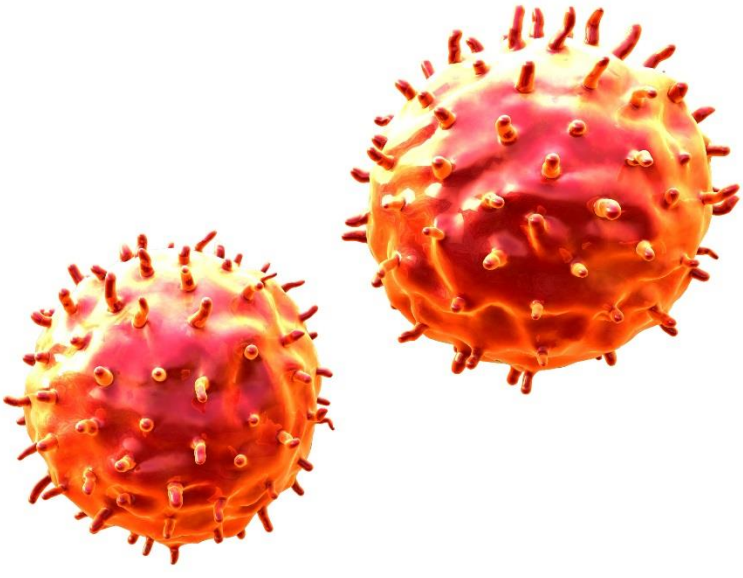
Teaching Pack

Biotechnology: juicing apples

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**



Version 2.0

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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*.	

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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 experiment 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*.

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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: Biotechnology – juicing apples

This *Teaching Pack* focuses on the use of enzymes in an industrial process (biotechnology).

Enzymes are used in the commercial production of apple juice. Pectinase increases the volume of juice extracted from apple pulp by weakening the apple cell walls after the pulp is crushed. It is also used to produce clear apple juice, so that customers have a choice of clear or cloudy.

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

- 20.2 Biotechnology

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

- evaluate methods and suggest possible improvements
- interpret and evaluate experimental observations

Prior knowledge

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

- 20.2 Biotechnology
- 2.1 Cell structure and organisation
- 5.1 Enzymes

Going forward

The knowledge and skills gained from this experiment will be useful for when you teach learners about other industrial uses of enzymes.

Briefing lesson: Evaluating methods and data

Resources	• a packet of A4 printer/photocopier paper • rulers and vernier calipers or micrometers • Worksheets A, B and C
Learning objectives	By the end of the lesson: • ***all*** learners should understand that there are often alternative ways to obtain the same data • ***most*** learners should be able to evaluate two or more different methods • ***some*** learners will be able to evaluate the observations and data likely to be obtained by different methods

Timings	Activity
15 min	**Starter/introduction** Ask groups of 2–4 learners to find the thickness of a single piece of paper. Provide each group with a different method: 1. a single sheet of paper and a ruler 2. a single sheet of paper and vernier calipers or a micrometer 3. a pile of 100 sheets of paper and a ruler 4. a pile of 100 sheets of paper and vernier calipers or a micrometer For methods 3 and 4, they measure the thickness of the pile and divide by 100. If vernier calipers or micrometers are not available, use methods 1 and 3 with the following alternatives to provide four different methods: 2. the single sheet of paper is measured flat or folded (divide the measurement, if folding to get thickness of one sheet) 4. learners measure the pile first, count the number of sheets and then divide the thickness by the number of sheets (some groups could count the number of sheets *before* measuring.) It might be necessary to explain that vernier calipers (or micrometers) measure to a greater degree of accuracy than a normal ruler. They measure to parts of a millimetre. After about 5 minutes, discuss as a class what happened in each group. The aim of the activity is for learners to understand that there is often more than one way to obtain the same result, but some ways might be easier than others and some ways might produce more accurate results. Points to discuss could include: • measuring a single sheet with a ruler with accuracy is impossible (only estimating is possible, not accurate measuring); • single sheets may vary slightly in thickness but a pile allows an average to be calculated; • counting sheets into a pile results in some air between each sheet compared to a tightly compressed pile straight from the packet; • folding a single sheet several times results in the spaces between the folds being included in the measurement; • measuring a pile with a better piece of apparatus might not produce a significantly more accurate average because of the number of sheets involved. *Continues on next page …*

Timings	Activity
	Main lesson
10 min	Give learners Worksheet A, which shows a simple process diagram for juicing apples on an industrial scale. Explain that in the next lesson, they will run/watch an equivalent process in the lab. In groups of 2–4, learners discuss the laboratory apparatus they think they would need for each stage. They write their choices on the worksheet. Discuss and agree the choices with the class.
20 min	It is important to help learners understand that there are many different ways to do the same thing; the choice of method to use will depend on a number of factors. Explain that Worksheet B contains pairs of alternative methods for doing the same thing at different stages of a process. Each group will evaluate one pair of alternative methods and present the strengths and weaknesses to the class. Make sure they understand that the process of evaluation involves considering the appropriateness of the method in terms of the purpose of the method; they should think in terms of the required degree of accuracy, the time it takes, and how easy it would be to do (for example, is it easily repeated?). Circulate the groups. Use the suggested answers to help guide the discussions if required. At the end of the activity, discuss the idea that all the methods will produce a result, but some are obtained more easily or more accurately. Often there is not a right or wrong method, just a case of deciding which advantages and disadvantages are the most appropriate for the investigation.
10 min	Now give learners Worksheet C and explain that choosing the appropriate equipment is just as important as choosing the appropriate method. Ask learners to answer the questions on the worksheet. You might need to prompt your learners, use the suggested answers to help you encourage the appropriate discussions. For question 1, ask if it would be appropriate to use a balance that has a degree of accuracy greater than two decimal places. Explain that there is no point in using a balance that reads to more than two decimal places because the method used involves processes that are likely to introduce errors larger than the degree of precision on the balance; and the measurements shown are sufficient to answer the investigation. At the end of the activity, discuss the idea that when an experiment requires the recording of very small changes in a given measurement, any errors introduced by poor choice of equipment, or careless working, could cause larger changes in the measurement than the difference you're trying to measure. So, it is very important to consider the choice of equipment and the method of recording carefully against what it is you're trying to measure. Ask learners to briefly review the equipment they selected for the process on Worksheet A. Do they still agree with their choices? What would they change? Why?
	Plenary
5 min	Summarise the key ideas from this lesson, that whilst there are often alternative ways to obtain the same data (that are faster/easier/lend to repeats more easily/more efficient/cheaper/more appropriate for available facilities), different methods and equipment can produce results with varying degrees of accuracy that may or may not be suitable for the purpose of the experiment.

Lab lesson: Option 1 – run the experiment

Resources	• Worksheets D, E, F, G, H and I • *Teacher walkthrough* video, *Teacher notes, Teacher method* • Equipment as outlined in the *Teacher notes*
Learning objectives	By the end of the lesson: • ***all*** learners should be able to follow a sequence of instructions and understand the importance of working safely • ***most*** learners should also be able to explain why there is a sample of apple incubated with just water • ***some*** learners will also understand the most appropriate equipment to generate data suitable for purpose.

Timings	Activity
10 min	**Starter/introduction** Remind learners that enzymes are used in the commercial production of apple juice to increase the yield of juice (if necessary, refer them to Worksheet A). Explain that they are going to run an experiment to *quantify* the effect of using the enzyme pectinase in the production of apple juice. Depending on your learners, you might want to give them Worksheet D, which explains the role of pectinase in this process. Give groups of learners a few minutes to consider the questions on Worksheet E and Worksheet F. Work through the evaluation activities as a class to consider the most suitable method and equipment to use for the experiment; learners make a note of the class decision. Note that Worksheet F focuses on the best way to measure the volume of juice collected.
45 min	**Main lesson** Briefly run through the method (Worksheet G) and equipment set-up (Worksheet H). Learners should collect and set up their equipment. Make sure you draw their attention to precautions they should take, for example, the care needed when cutting and pulping the apple, and using the pectinase solution. Emphasise that they absolutely must **not** drink the apple juice they collect as glassware might contain chemicals from previous experiments that are dangerous to health. **Safety** Circulate the classroom at all times during the experiment so that you can make sure that your learners are safe. When they have their work space organised, your learners can begin the experiment. Tell them to follow the method shown on Worksheet G and record their observations and data in the table on Worksheet I. Ask them to think of any possible problems with the method and equipment they're using as they go along, and to note these down on Worksheet I
5 min	**Plenary** Discuss the difference in appearance between the two sets of apple juice collected, and the different volumes of juice obtained from the two samples. Discuss what the results show about the effectiveness of pectinase in the production of apple juice. You will interpret these results in more detail in the next lesson.

Teacher notes

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

Each group will require:

- apples × 2
- pectinase solution
- distilled water
- a sharp knife or scalpel
- a white tile
- 100 cm^3 beaker × 2
- glass rod × 2 (or wash glass rod between uses)
- 100 cm^3 measuring cylinder × 2 (smaller measuring cylinders would be preferable if available)
- funnel × 2
- coffee filter × 2
- cling film
- stop clock / timer (accurate to 1 second)
- 10 cm^3 syringe × 2
- large spatula or spoon × 2
- balance
- water bath and thermometer (if required)
- muslin (if required)

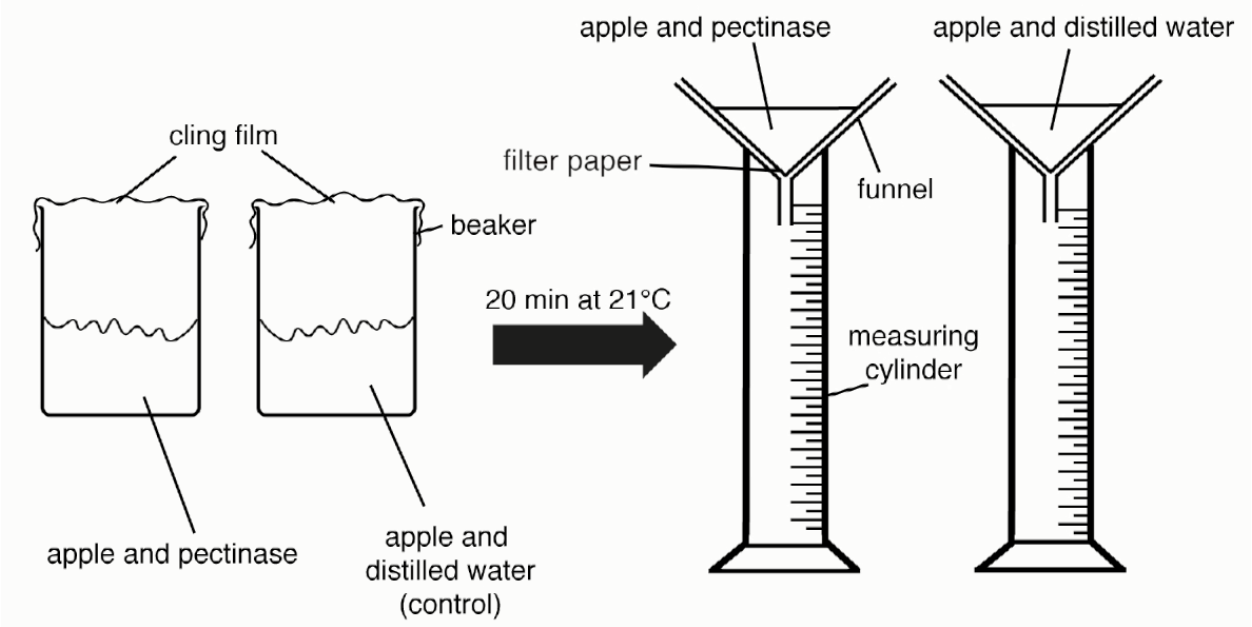
Safety

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

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

Substance	Hazard	First aid
Enzymes, concentrated solutions	IRRITANT	**In the eye:** Flood the eye with gently-running tap water for at least 10 minutes. See a doctor. **Swallowed:** Wash out the mouth. Give a glass of water to drink. Do not make the casualty vomit. See a doctor. **Dust breathed in:** Remove the casualty to fresh air. See a doctor if breathing is difficult. **Spilt on the skin or clothing:** Remove contaminated clothing. Wash off the skin with soap and plenty of water. Rinse contaminated clothing. **Spilt on the floor, bench, etc.:** Scoop up powders (take care not to raise dust). Wipe up solution spills or any traces of powders with a damp cloth.
Enzymes, dilute solutions	LOW HAZARD	**In the eye:** Flood the eye with gently-running tap water for at least 10 minutes. See a doctor. **Swallowed:** Wash out the mouth. Give a glass of water to drink. Do not make the casualty vomit. See a doctor. **Dust breathed in:** Remove the casualty to fresh air. See a doctor if breathing is difficult. **Spilt on the skin or clothing:** Remove contaminated clothing. Wash off the skin with soap and plenty of water. Rinse contaminated clothing. **Spilt on the floor, bench, etc.:** Scoop up powders (take care not to raise dust). Wipe up solution spills or any traces of powders with a damp cloth.
Food	Allergies	Do not consume any foodstuffs in the labs. 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 for this experiment.

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

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/materials required
- if you intend asking your learners to incubate the apple pulp in a water bath
- if you intend your learners to use muslin to enable the apple pulp to be compressed

Experiment

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

Steps	Notes
1. Learners should collect all the equipment they need from the front of the class.	
2. Learners use a sharp knife to cut two apples into approximately 5 mm × 5 mm pieces.	*Cutting should be done on a white tile. Remind learners to be careful with sharp knives. There is no need for the apples to be peeled.*
3. Learners then add 50 g to 1 decimal place (1dp) of apple pieces to two beakers.	*The apple pieces should be added to the beakers on a balance set to zero. It is important that each beaker contains as near to 50 g as possible, so careful adjustment (adding or taking away apple pieces) might be needed.*
4. Using the glass rod, learners should gently pulp (break up) the pieces in each beaker.	
5. They should label one of the beakers with the letter ‘E’ (enzyme) and the other with the letter ‘C’ (control) using a glassware pen or sticky label.	
6. Learners should then cover each beaker with cling film.	*The cling film prevents any evaporation of water from the apple, which might alter the volume of juice produced.*

Steps	Notes
7. 4 cm^3 of distilled water should be added to the beaker of apple labelled 'C'.	*Different syringes must be used for enzyme solution and distilled water. Warn learners to be ready to start the stop clock immediately upon addition of the enzyme solution. You could ask learners why this is important (as the pectinase will start working immediately). Remind learners that enzymes can cause allergic reactions, so skin contact should be avoided.*
8. 4 cm^3 of pectinase solution should be added to the beaker of apple labelled 'E'. At this point, learners must start the stop clock.	
9. Learners should stir the apple with a glass rod after each reagent has been added and recover with cling film.	*Learners must be careful to clean the glass rod between stirring each beaker to avoid contaminating the control with enzyme solution.*
10. Learners will then leave the beakers to incubate in one of two ways: i. leave at room temperature for 20 minutes ii. leave for 15 minutes in a water bath set at the optimum temperature for the pectinase being used.	*The water-bath option might result in higher volumes of juice and/or speed up the reaction so the incubation can be done for less time. The juice yield varies with different sorts of apple and different pectinases. It might be worth trialling the experiment beforehand to see if a higher incubation temperature gives a bigger difference between the control and the enzyme solution and speeds up the reaction to make better use of time in the lesson.*
11. Learners should place a funnel and coffee filter paper into two measuring cylinders, labelled 'C' and 'E'.	
12. After the incubation period, learners should empty the beakers into the correct funnels.	*Ensure that learners fully empty the material in each beaker by scraping them out with a spoon or spatula. Remind them to take care to empty each beaker into the correct measuring cylinder to avoid muddling the samples.*
13. Learners should wait until there is no more juice dripping from either funnel.	*This can take 10–15 minutes. If time is limited, juice extraction can be sped up by gently squeezing the apple pulp but learners must take care not to tear the filter paper. Squeezing is made easier if several layers of muslin are placed inside the coffee filter. However, it is difficult for learners to control the amount of compression, potentially leading to invalid results.*

Steps	Notes
14. Learners should read off the volume of juice in each measuring cylinder and record each volume.	*Make sure learners know how to read the volume correctly, i.e. with the cylinder on a flat surface, have their eyes at the level of the liquid in the cylinder, and read the measurement from the bottom of the meniscus.*
15. They should also note the appearance of the juice in each measuring cylinder.	*Remind learners that they should **not** drink the apple juice!*

Clean-up

After the experiment learners should:

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

Lab lesson: Option 2 – virtual experiment

Resources	• *Virtual experiment* video • Worksheets D, E, F, and J (Worksheet H is optional) • Stopwatches / timers / clocks
Learning objectives	By the end of the lesson: • ***all*** learners should be able to follow a sequence of instructions and understand the importance of working safely • ***most*** learners should also be able to explain why there is a sample of apple incubated with just water • ***some*** learners will also understand the most appropriate equipment to generate data suitable for purpose.

Timings	Activity
15 min	**Starter/introduction** Show the introduction to the video (it will automatically pause on the Equipment shot). Ensure that your learners understand that the experiment involves quantifying the effectiveness of pectinase in obtaining juice from apples. (You might want to give some learners Worksheet D, which explains the role of pectinase.) Ask learners to explain how pectinase would help to increase the amount of juice that can be obtained from apples. Give learners Worksheet E and Worksheet F. Discuss the evaluation methods as a class, agreeing on the most suitable method and equipment to use in each case; learners make a note of the class decisions. Note that Worksheet F focuses on the best way to measure the volume of juice collected.
10 min 15 min 5 min	**Main lesson** Arrange learners into groups (2–4), and give each learner Worksheet J, and a stopwatch, timer or clock. Explain that Worksheet J is a set of instructions for the lesson that they need to follow. Explain that they will now watch a video of the experiment (you could also give them Worksheet H) and they should start following the instructions on Worksheet J. Resume play of the video. Instruction 1 on the worksheet asks them to note down any possible problems with the method and equipment used. The video will automatically pause before the results are shown. The learners are told to wait until the video pauses before carrying out an ordering activity (Instruction 2). They are told they have 10 minutes to do the activity and should time themselves. They need to keep an eye on the time to make sure they finish the activity in the time given. Set a timer yourself for 10 minutes, so that you can call a stop to the activity after that time. Circulate the room as learners do the activity, to make sure they are keeping an eye on the time. Once the activity is finished, quickly discuss the order as a class and resolve any misconceptions; agree if alternative orders are correct. Now discuss the answers to questions 1–3 on the video (Instruction 3). When you click on the 'Video question' button a pop-up will appear and the video will pause. *Continues on next page …*

Timings	Activity
	**Main lesson continued …** Explain that you will resume play of the video again and they need to follow the next set of instructions on Worksheet J (Instructions 4 and 5). Resume the play of the video, it will pause automatically on a shot of the two measuring cylinders so results can be recorded. Resume play of the video again and it will pause to reveal the volume in each measuring cylinder; learners can check if these match what they recorded. Discuss and resolve any discrepancies. Note that the rest of the video discusses the results, which will covered in the *Debriefing lesson*.
	**Plenary** Discuss what the results show about the effectiveness of pectinase in the production of apple juice. Explain that you will interpret these results in more detail in the next lesson.

Debriefing lesson: Interpreting results

Resources	• Learners' completed Worksheets E, F, I and J • Worksheets K and L • *Virtual experiment* video
Learning objectives	By the end of the lesson, • ***all*** learners should be able to calculate percentage increase • ***most*** learners should also understand the advantage of using mean values • ***some*** learners will also be able to explain the advantages of interpreting the results as a percentage increase.

Timings	Activity
10 min	**Starter/introduction** 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.
15 min	**Main lesson** Explain that it is more meaningful to interpret the results of the apple juicing experiment by calculating the percentage increase in volume, than it is to simply calculate the difference in volume. Give learners Worksheet K and ask them to use their results (recorded on Worksheets I or J) to calculate the percentage increase of juice produced by using pectinase. Explain that the percentage increase in juice is a better way to interpret the result than the difference in juice produced because it makes it possible to compare individual results regardless of differences in the starting size or mass of the sample used; it helps to standardise any variation in the quantity of apple tissue in the different samples, which is important when calculating the mean. Even though great care was taken to ensure the same mass of apple was used throughout, there are various steps where the volume of the samples might have varied. It can also be an easier way to visualise the increase than raw volumes when you have a number of repeats. Essentially, provided that all apple samples have been treated in the same way, the percentage increase quantifies the effect of using the enzyme in a way that allows a valid comparison with repeated measurements, even if the type of apple or filter paper is different. Now pool the class data (or use the data provided on page 2 of Worksheet K if you did *Lab Lesson: Option 2*) to calculate a mean percentage increase for the whole class. Remind learners that a mean value is a better way to interpret the result because it allows anomalies to be detected and/or reduces their effect on the overall result. Also, by pooling their data, they have effectively made repeats of the experiment, which will make the results more reliable. Ask learners to interpret the data and write a conclusion. They should determine that the addition of pectinase increases the volume of apple juice produced in a given time by *x*% and that is also produces clear apple juice. You might want to show them the rest of the *Virtual experiment* video (from 6:22 to the end). *Continues on next page …*

Timings	Activity
	**Main lesson continued …** Explain that you want them to write up an evaluation of the method used, including an evaluation of the data they collected and how suitable it is for the purpose of the experiment. They should also include the potential improvements, together with justification of their choices. Tell them to use the notes they made on Worksheet I or Worksheet J and their answers to Worksheet E to help them identify and note down the strengths and weaknesses of their data and method. They can use their analysis of the alternatives given on Worksheet E to suggest improvements that they might make to the method either by using different apparatus or a different technique. You might want to provide some scaffolding to support your learners in this extended writing task; this is provided on Worksheet L. The learners are first asked a series of questions to help get them thinking about the method, then they are given some tips on what to include and a checklist.
	**Plenary** Discuss with your learners whether they feel the degree of accuracy of their results, and the method used, was sufficient to confidently quantify the increase in juice yield from apples resulting from the use of pectinase.

Worksheets and suggested answers

	Worksheets	Suggested answers
For use in the *Briefing lesson:*		
A: Industrial apple juice production	**20–21**	**38**
B: Evaluating alternative methods	**22**	**39**
C: Evaluating data	**23–24**	**40**
For use in *Lab lesson: Option 1:*		
D: The action of pectinase	**25**	**—**
E: Evaluating alternative methods	**26**	**41**
F: Evaluating data	**27**	**42**
G: Method	**28–29**	**—**
H: Equipment set-up	**30**	**—**
I: Recording your results	**31**	**43**
For use in *Lab lesson: Option 2:*		
D: The action of pectinase	**25**	**—**
E: Evaluating alternative methods	**26**	**41**
F: Evaluating data	**27**	**42**
H: Equipment set-up	**30**	**—**
J: Instructions	**32–33**	**44**
For use in the *Debriefing lesson:*		
K: Interpreting the results	**34–35**	**46**
L: Evaluation and improvements	**36–37**	**47**

Worksheet A: Industrial apple juice production

The **industrial** apple juicing process has the following stages.
In each box, list any equipment from page 2 that would be needed to carry out these steps if they were carried out in a **laboratory**.

Selection and washing of apples

Equipment:

Mincing / pulping of apples

Equipment:

Incubation of pulp with enzyme

Equipment:

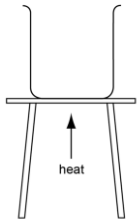
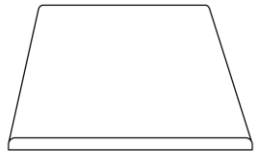
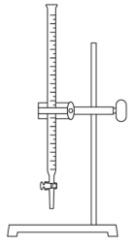
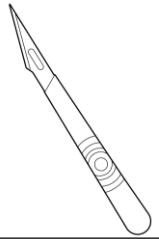
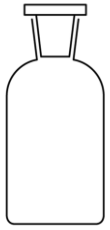
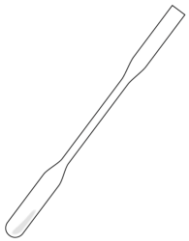
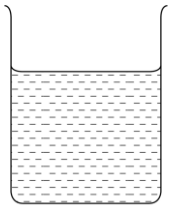
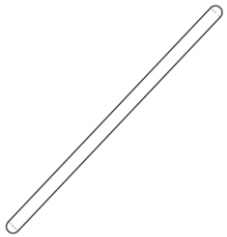
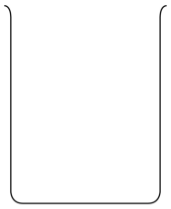
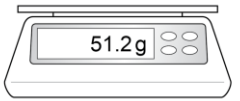
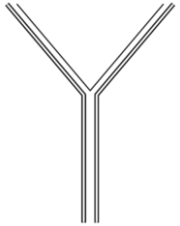
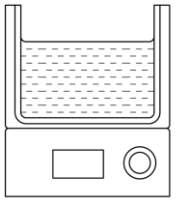
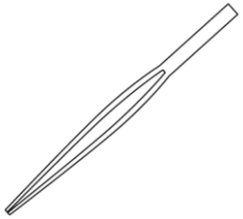
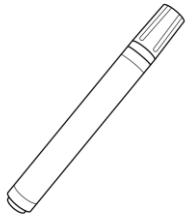
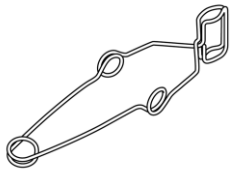
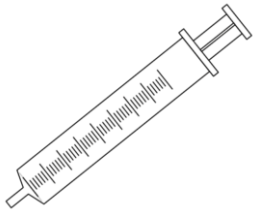
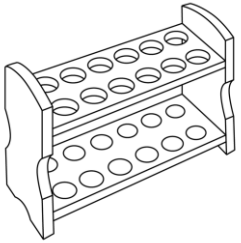
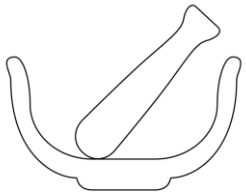
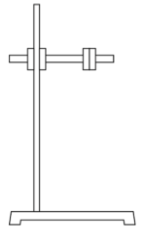
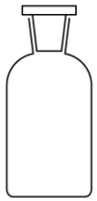
Filtration of pulp

Equipment:

Measuring juice into containers

Equipment:

Here is a list of common equipment found in a laboratory. Select what you would use for each stage on page 1.

						
dropper pipette	distilled water	timer	Bunsen burner & tripod	boiling tubes & test-tubes	white tile	buret
						
scalpel	iodine solution	spatula	beaker of water	glass rod	beakers	balance
						
thermometer	funnel & filter paper	water bath	forceps	dropper pipette	measuring cylinder	evaporating dish
						
test-tube holders	syringe	rack	conical flask	pestle & mortar	clamp	enzyme

Worksheet B: Evaluating alternative methods

Pieces of potato can be used to investigate the effects of osmosis on plant tissues. Small pieces of potato tissue are left for a period of time in sucrose solutions of different concentrations and any changes are measured.

A to **D** describes a series of stages in this experiment.

(a) What is the purpose of each stage?
(b) There are two alternative methods for each stage. What are the strengths and weaknesses of each alternative?

A1 Cut some potato into small cubes of side length 1 cm using a knife and a ruler.	**A2** Cut some potato into small cylinders 1 cm in length by using a cork borer, and a knife to cut each cylinder approximately in half.
↓	↓
B1 Plan to measure the change in mass of each potato piece. Record the starting mass of each potato piece.	**B2** Plan to measure any change in volume of each potato piece. Record the starting volume of each piece.
↓	↓
C1 Leave the pieces of potato in the different sucrose solutions for 20 minutes and then measure the mass of each piece.	**C2** Leave the pieces of potato in the different sucrose solutions until no further change in volume is measured.
↓	↓
D1 Repeat the measurements for each sucrose concentration by using three pieces of potato in separate test-tubes (for each concentration). This creates four measurements for each sucrose concentration.	**D2** Repeat the measurements for each sucrose concentration by using three pieces of potato, all placed into the same small beaker (for each concentration); this batches the repeats. This creates four measurements for each sucrose concentration.

Worksheet C: Evaluating data

Evaluating data involves deciding if it is suitable for the purpose of your experiment.

Some students run an experiment to investigate the effects of osmosis on pieces of plant tissue. They want to find the sucrose concentration that leads to the smallest change in mass of the plant tissue. The results tables below show the measurements taken from the **same** samples but obtained using different equipment.

A

Sucrose conc. / %	Mass / g	
	Start	Final
0	2	2
10	2	2
20	2	2
40	2	2
60	2	2

B

Sucrose conc. / %	Mass / g	
	Start	Final
0	2	2.5
10	2	2.0
20	2	2.0
40	2	1.5
60	2	1.5

C

Sucrose conc. / %	Mass / g	
	Start	Final
0	2.1	2.3
10	1.9	2.0
20	2.0	1.9
40	1.6	1.4
60	1.8	1.5

D

Sucrose conc. / %	Mass/ g	
	Start	Final
0	2.13	2.25
10	1.94	1.96
20	2.04	1.94
40	1.63	1.40
60	1.81	1.52

1. Evaluate the data: for each table, give your view of the suitability of the data for finding the sucrose concentration that results in the smallest change in mass. Explain your answer.

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2. A car manufacturer is developing a new hybrid car (petrol engine and electric motor). They measure the maximum distance the car can travel before it needs to be recharged. The following distances were recorded using different equipment. Which is the most appropriate for what the car manufacturer requires? Why?

Equipment A: 280 km **Equipment B**: 280.023 km

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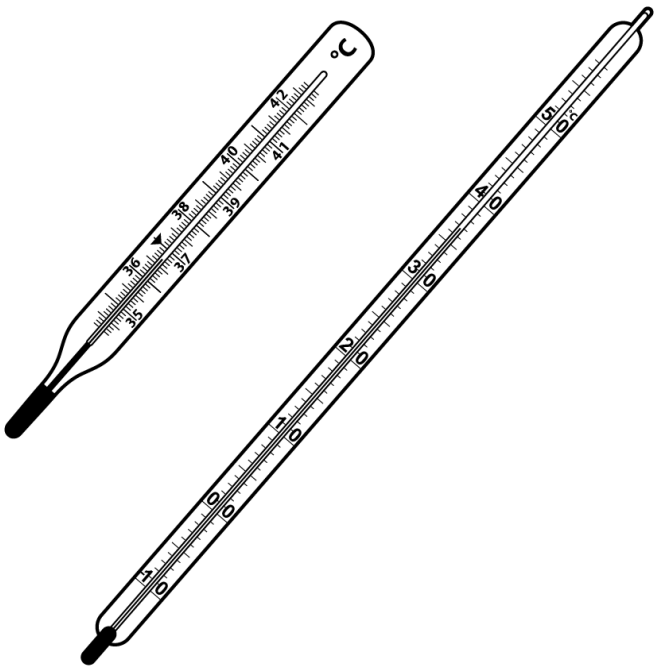
3. The data shows the normal fluctuations in human body temperature over a 24-hour period. Which thermometer would you choose for collecting more data like this and why? Why would the other thermometer not be appropriate?

Time	Temperature / °C
03:00	36.5
06:00	36.3
09:00	36.7
12:00	37.1
15:00	37.3
18:00	37.4
21:00	37.2
24:00	37.0



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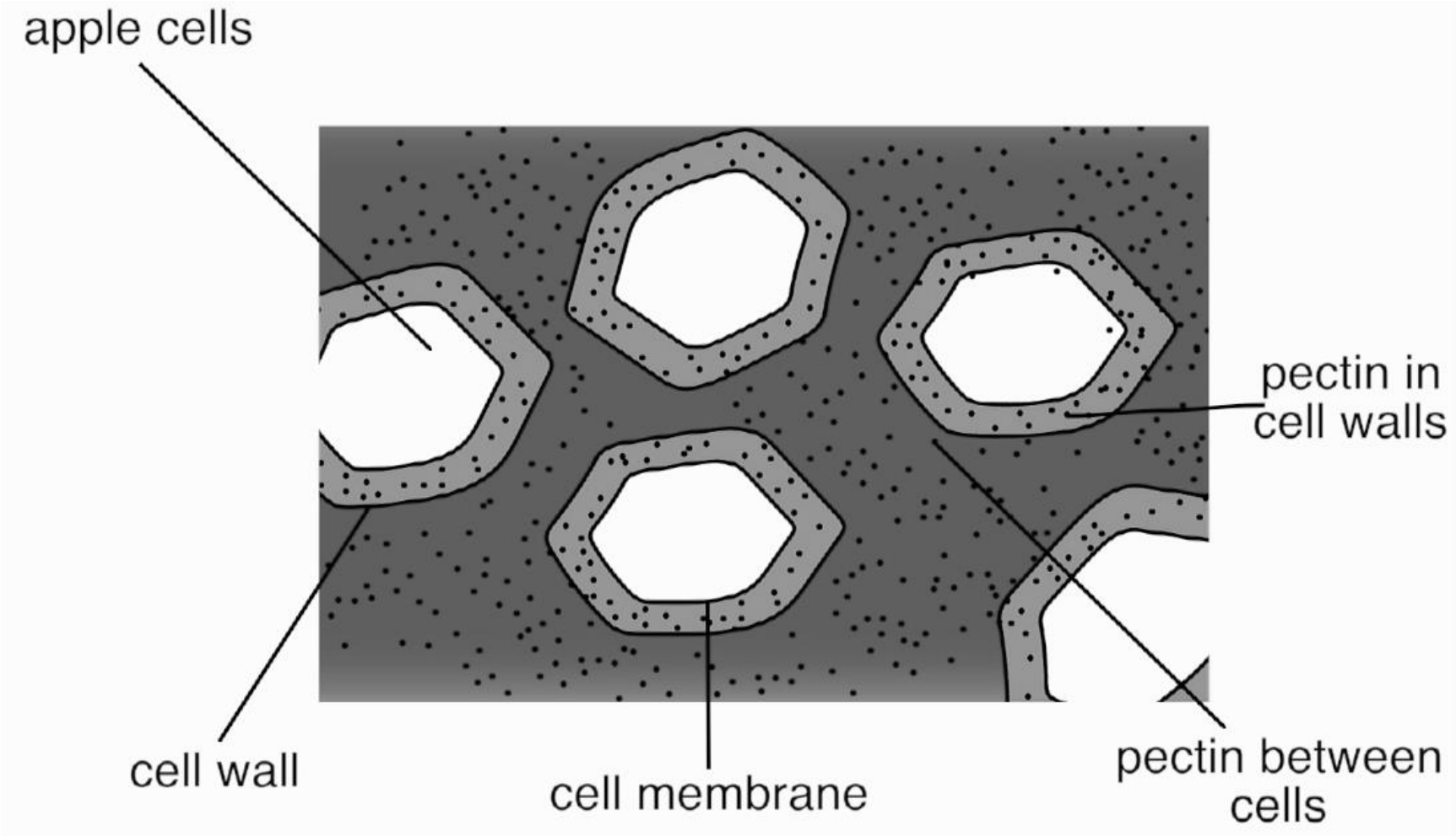
Worksheet D: The action of pectinase

Pectinase increases the volume of apple juice collected by catalysing a reaction that releases juice from the cells. Pectin is a substrate for pectinase. Pectin is found in the middle lamella between apple cells and within the cell wall. The middle lamella holds the cells together. Pectinase breaks down the pectin in the middle lamella causing cells to separate more easily; it also breaks down the pectin in the cell walls. This weakens the cell walls, helping the cells to burst open and release juice.



Worksheet E: Evaluating alternative methods

To test the efficiency of pectinase at increasing the yield of apple juice, two samples of apple are used. Note that pectinase has an optimum temperature of 50°C – 60°C.

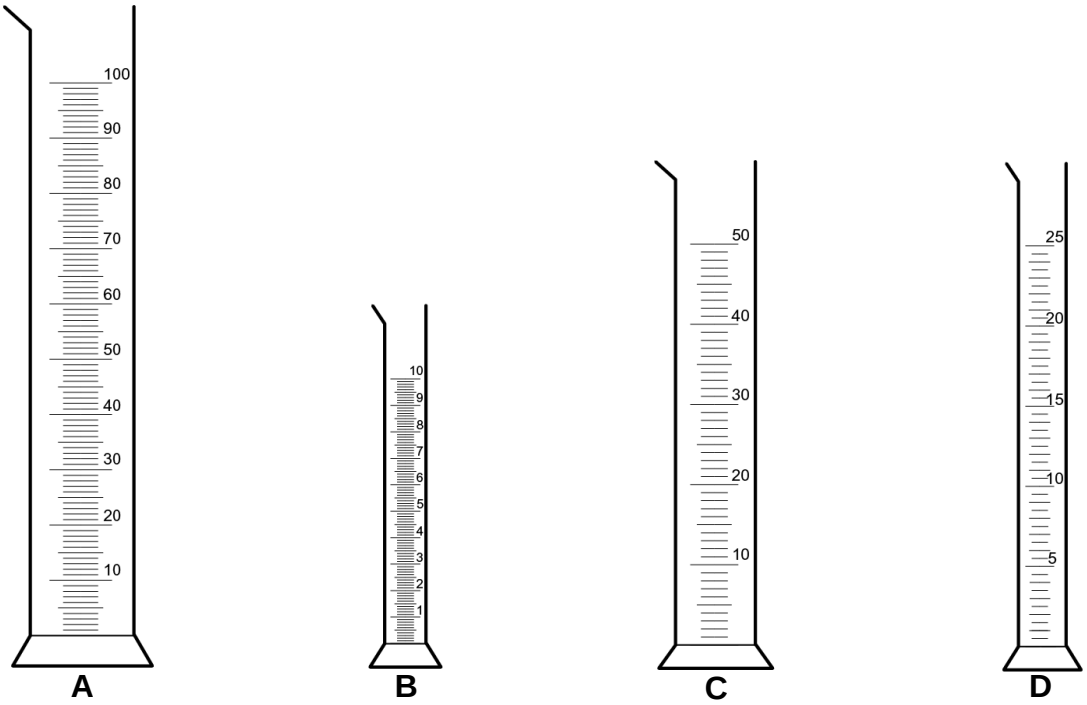
A to **E** describes a series of steps in this experiment. For each step, consider the following:

(a) What is the purpose of the step?
(b) There are two alternative methods for each step. What are the strengths and weaknesses of each alternative?

A1 Count out the same number of apple pieces into each sample.	**A2** Measure the same mass of apple into each sample.
↓	↓
B1 Crush the apple into pulp before adding the pectinase solution.	**B2** Cut the apple into very small pieces before adding the pectinase solution.
↓	↓
C1 Add pectinase solution to one sample of apple.	**C2** Add pectinase solution to one sample of apple and add the same volume of distilled water to a second sample of apple.
↓	↓
D1 Leave the apple samples to incubate for 15 minutes in a water bath set at 50°C.	**D2** Leave the apple samples to incubate for 20 minutes at room temperature.
↓	↓
E1 Filter the apple pulp through filter paper to extract the juice.	**E2** Squeeze the apple pulp through muslin cloth to extract the juice.

Worksheet F: Evaluating data

The volumes of juice obtained from small samples of apple in laboratory experiments are usually between 5 cm^3 and 40 cm^3. Therefore, the difference in volume between two samples being compared is often very small. Remember that your choice of equipment, and method, should be appropriate for the purpose of your experiment.



1. Sort each measuring cylinder in the appropriate box below.

Could be appropriate	Definitely not appropriate

2. Which would be the **most** appropriate measuring cylinder to use to measure the volumes of juice obtained? Explain your reasoning (including why others are not appropriate).

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3. Why is it very important that **all** of the apple pulp is transferred from each sample into the filter?

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Worksheet G: Method

Follow the instructions to carry out the experiment. Answer the questions as you go along.

1. Collect your equipment.

2. Use a sharp knife to cut two apples into pieces roughly 5 mm × 5 mm in size; just estimate the size by eye.

Take care when using a sharp knife. Always cut in a downward motion away from your body, onto a white tile. Keep fingers away from the blade.

3. Measure out 50 g to 1 decimal place (1 dp) of apple pieces into two beakers. One sample at a time, place the beaker onto the balance and press the 'Tare/Zero' button to reset the mass to zero; this means that the mass of the beaker has been subtracted. Add apple pieces until the balance reads 50 g (1 dp).

Make sure there is the same mass of apple in each sample.

4. Gently pulp the pieces using a glass rod; use an upward and downward motion to mash up the pieces until they form a pulp. Be careful not to break the beaker or the glass rod.

If you break the glass rod or the beaker, inform your teacher immediately to clean it up safely.

5. Label one beaker 'E' (for 'with enzyme') and label the other 'C' (for 'control').

6. Cover each beaker with cling film.

7. Add 4 cm^3 of distilled water to the beaker labelled 'C', stir with a clean glass rod and recover with the cling film.

8. Add 4 cm^3 of pectinase solution to the beaker labelled 'E', stir with a clean glass rod and recover with the cling film.

Do not forget to recover with cling film.

9. Immediately start the timer once the pectinase is added.

Why do you need to start the stop clock immediately?

10. Leave the apple samples for 20 minutes at room temperature, or for 15 minutes in a water-bath (your teacher will tell you which you will do).

Take care when handling hot water and hot glassware.

11. Place a funnel into each of two measuring cylinders.

12. Put a coffee filter into each funnel.

13. Label one measuring cylinder ‘E’ and label the other ‘C’.

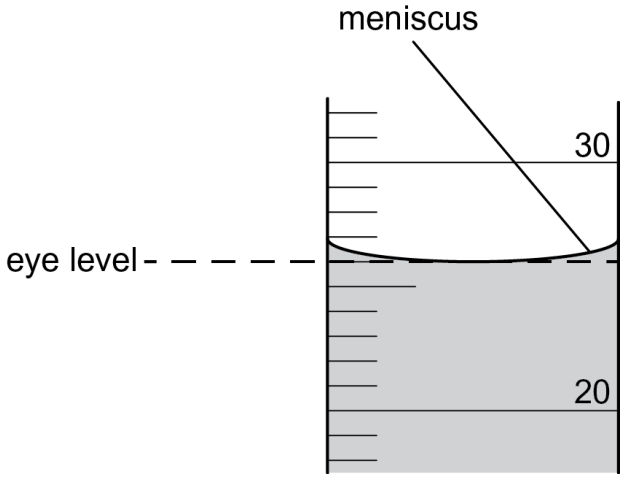
14. After incubation is finished, completely empty the beakers into the funnels.

Make sure that you empty the beakers into the correctly labelled measuring cylinders.

15. The juice will start dripping into the measuring cylinder. Wait until there is no more juice dripping from either funnel.

This might take around 10 to 15 minutes.

16. Record the volume in each measuring cylinder in the table on **Worksheet I**. The volume of the liquid should be read from the meniscus of the liquid.

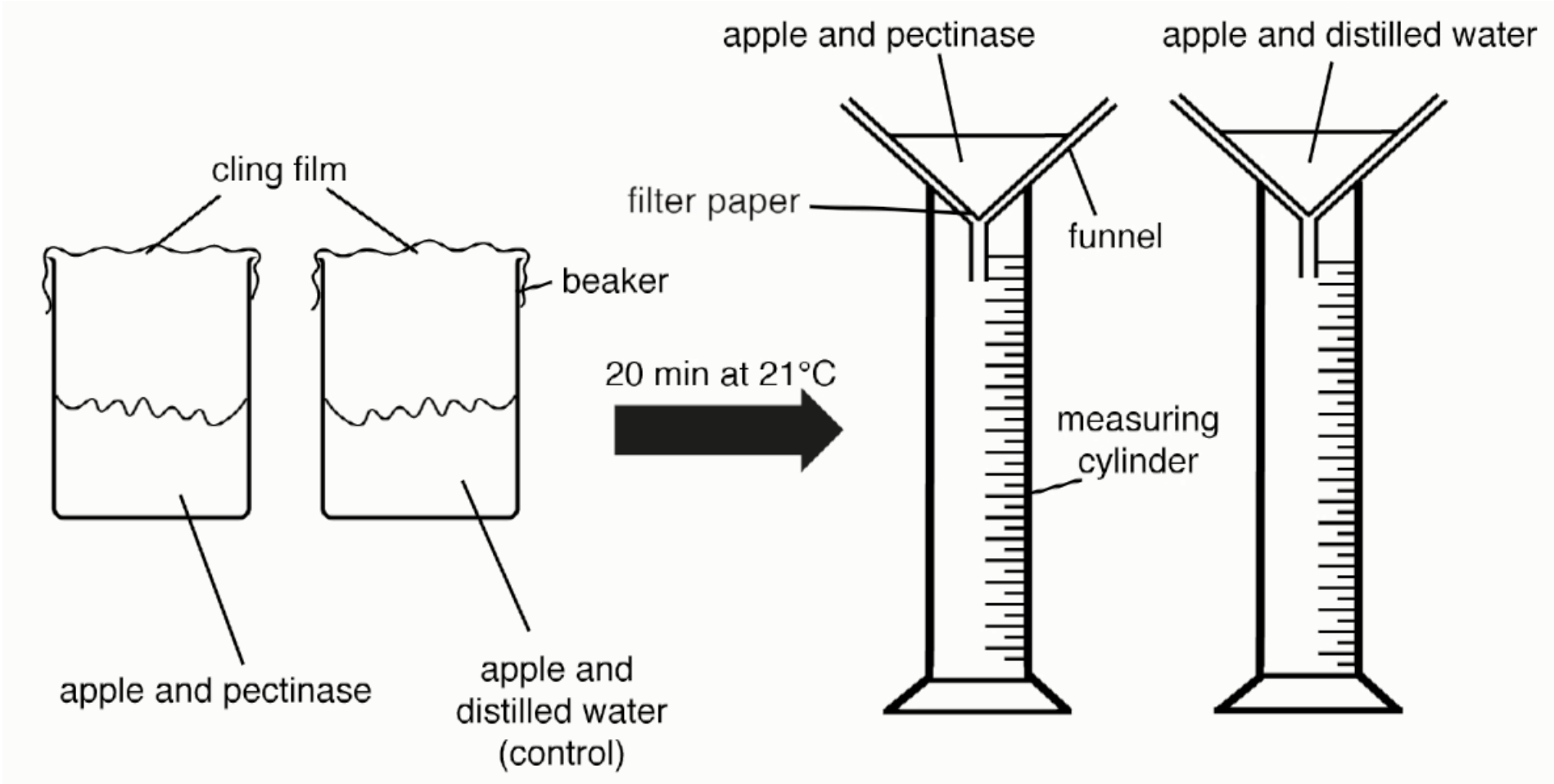


17. Note down any observations you have about the appearance of the juice on Worksheet I.

18. Calculate the difference in volume of apple juice contained between the two samples.

What does the difference in volume suggest about adding pectinase to the apple sample?

Worksheet H: Equipment set-up



Worksheet I: Recording your results

1. Write down any possible issues with the method and equipment used:

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2. Record your results in the table.

Sample	Volume of apple juice collected / cm^3
C (without pectinase)	
E (with pectinase)	

3. Observation about appearance of the apple juice in each sample:

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Worksheet J: Instructions

Instruction 1: Watch the first part of the video and make notes of any possible problems with the method and equipment used. Use the space below. As soon as the video pauses, move on to **Instruction 2**.

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Instruction 2:

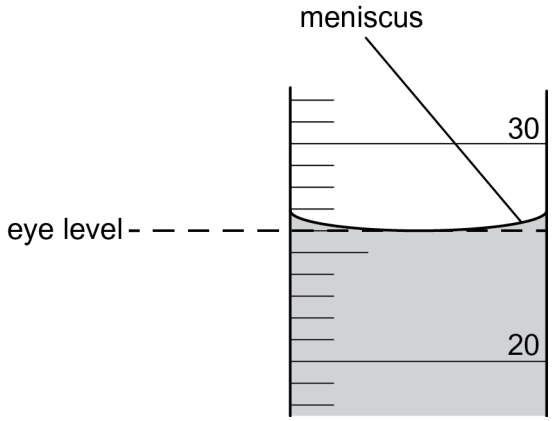
As soon as the video pauses, complete the ordering activity on page 2 of this worksheet. You have **10 minutes** to complete the ordering task and then you must stop. Keep track of the time as you do the task to make sure you do not run out of time. Cut out the steps and put them in the correct order in the table provided.

Instruction 3:

After you have completed **Instruction 2**, your teacher will reveal some questions on the video. Discuss the answers as a class.

Instruction 4:

Carry on watching the video. The volume of the liquid should be read from the meniscus of the liquid. Record your results in the table provided.



Sample	Volume of apple juice collected / cm^3
C (without pectinase)	
E (with pectinase)	

What is different about the appearance of the juice in each sample? Why might this be?

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Instruction 5: Calculate the difference in volume of juice produced by the two samples.

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1		**10**	
2		**11**	
3		**12**	
4		**13**	
5		**14**	
6		**15**	
7		**16**	
8		**17**	
9		**18**	

Place the beaker on the balance and press the ‘zero/tare’ button to set the mass to zero.	Add 4 cm^3 of pectinase solution to the beaker labelled ‘E’, stir with the glass rod and re-cover with cling film.
Immediately start the stop clock.	Leave the apple samples for 20 minutes at room temperature.
After 20 minutes, completely empty the beakers into the funnels.	Label one measuring cylinder ‘E’ and label the other ‘C’.
Put a coffee filter into each funnel.	Add apple pieces to the beaker until there is 50 g (1 dp).
Read off and record the volume in each measuring cylinder.	Break up the apple pieces in each beaker using a glass rod.
Calculate how much extra juice was obtained from the sample of apple by using pectinase solution.	Cover each beaker with cling film.
Cut pieces of apple about 5 mm × 5 mm in size.	Wait until there is no more juice dripping from either funnel. (This can take 10–15 minutes.)
Add 4 cm^3 of distilled water to the beaker labelled ‘C’, stir with the glass rod and re-cover with cling film.	Collect the equipment and set it up.
Place a funnel into each of two measuring cylinders.	Label one beaker ‘C’ (for control) and one ‘E’ (for enzyme).

Worksheet K: Interpreting the results

1. Use the following formula to calculate the percentage increase in apple juice produced.

$$\textbf{percentage increase in volume of apple juice} = \frac{\textbf{difference in volume of apple juice}}{\textbf{volume of apple juice in control}} \times \textbf{100}$$

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Percentage increase = …….

2. Use the class data to calculate a mean percentage increase.

$$\textbf{mean percentage increase} = \frac{\textbf{sum of percentage increase in each repeat}}{\textbf{number of repeats}}$$

= …….

3. Use your interpretation of the results to write a conclusion.

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For use with Lab lesson: Option 2 – virtual experiment

The experiment in the video was repeated five more times to obtain the following results.

Use these values to calculate the mean percentage increase in apple juice.

Repeat	1	2	3	4	5	6
Percentage increase in apple juice obtained by using pectinase (%)	68	61	65	67	65	66

Worksheet L: Evaluation and improvements

Use this worksheet to help you write up the evaluation of the juicing apple experiment. Start by answering the following questions to get you to think about the method. Then use the checklist on the next page to help you write up your evaluation.

1. Why is it important to use the same mass of apple in each sample?

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2. Why do you need to cover the samples with cling film?

   ……...

   ……...

3. Why do you need to use a control experiment?

   ……...

   ……...

4. Why do you need to stir the sample? Why do you need to use a clean glass rod?

   ……...

   ……...

5. Why do you need to start the stop clock immediately after the pectinase is added? Why is the pectinase added last? Why is the pectinase sample emptied into the filter first?

   ……...

   ……...

6. Why do you need to leave **both** samples for the same amount of time at the same temperature?

   ……...

   ……...

7. Why is it important to completely empty both beakers?

   ……...

   ……...

Evaluation

Your evaluation should include:

- what you think were the strengths of your experiment
- what you think were the weaknesses of your experiment.

Make sure you explain your reasoning in each case.

Writing checklist

1. I have included:
   - the amount of time the experiment took and the implications of this for doing repeats ☐
   - how easy it was to carry out each step and the implications of this for doing repeats ☐
   - possible sources of error, explaining why they are sources of error ☐
2. I have been specific and explained what worked well and what did not work well, and supported these statements with explanations as to why. ☐
3. I have written a balanced evaluation by including both the strengths and weaknesses, using connectives such as ‘although’ and ‘however’. ☐

Improvements

Your suggestions for improvements should include:

- what problems you experienced, and why they were a problem
- how you could solve the problems if you did the experiment again by using different equipment or a different method.

Writing checklist

1. I have identified each of the problems I had. ☐
2. I have explained why each problem is a problem, for example, in relation to the accuracy of the results. ☐
3. I have used a range of linking words such as, ‘because’, ‘so’, ‘since’ to extend my writing. ☐

Worksheet A: Suggested answers

Learners' own suggestions. Ideas might include:

Selection and washing of apples	no laboratory equipment required
Mincing / Pulping of apples	scalpel, white tile, pestle and mortar
Incubation of pulp with enzyme	beaker, water bath, thermometer, enzyme
Filtration of pulp	beaker/measuring cylinder, clamp, filter funnel, filter paper
Measuring juice into containers	measuring cylinder

Worksheet B: Suggested answers

A1 and A2

(a) Each sample of potato needs to be small enough to fit into a boiling tube or small beaker; if samples are too large then it might take too long for measurable effects of osmosis to be recorded.
(b) Cutting the same-sized cylinders using a cork borer is easier and less time-consuming than cutting the same-sized cubes (strength for A2, weakness for A1). However, cutting the resulting cylinders approximately in half without using a ruler means sample sizes are not exactly the same, so the method is less accurate (weakness for A2, strength for A1).

B1 and B2

(a) It is necessary to measure if there is any change in the potato tissue due to the uptake or loss of water.
(b) Measuring the mass of the potato cylinders is problematic because if the cylinders are not dried off properly after being submersed in the sucrose solution, the additional liquid can cause errors in the recorded mass, which are larger than the small changes in mass caused by osmosis (weakness for B1, strength for B2). However, recording the volume requires making several measurements for each piece (length, width and depth) and also involves a calculation, so measuring the mass is quicker and easier (strength for B1, weakness for B2).

C1 and C2

(a) In order to record a measurable change in the potato tissue, enough time needs to be allowed for osmosis to take place.
(b) Leaving the potato pieces for 20 minutes allows results to be obtained in a reasonable period of time, and is easier than having to repeatedly take measurements until no further change is detected (strength for C1, weakness for C2). However, leaving the potato until no further change is detected does allow the tissue to equilibrate with the solution and gives the maximum change for each solution (strength for C2, weakness for C1).

D1 and D2

(a) Repeat measurements allow a mean value to be calculated, which allows anomalies to be detected and/or reduces the effect of anomalies.
(b) The potato pieces are all identical (as far as possible) so placing them in separate containers means that the initial masses recorded for the pieces are not muddled and avoids the need to calculate a mean initial value before osmosis takes place (strength of D1, weakness of D2). However, batch processing the pieces in terms of draining, drying and measuring them is more time efficient (weakness of D1, strength of D2).

Worksheet C: Suggested answers

1. **A**: Mass recorded to the nearest 1 g does not detect any changes.

   B: Mass recorded to the nearest 0.5 g does not discriminate enough to decide which solution gives the smallest change in mass.

   C: Mass recorded to the nearest 0.1 g indicates the change more accurately than **B** but still does not discriminate enough to decide which solution gives the smallest change in mass.

   D: For the purpose of this investigation, mass recorded to the nearest 0.01 g is the only suitable measurement.

   The data recorded to two decimal places is the only set of data that can discriminate effectively between the different sucrose concentrations.

2. Equipment A. Measuring to the nearest kilometre is sufficiently accurate.

   280 km = 280 000 m and 280.023 km = 280 023 m; so the difference in measurement is 23 m. When the maximum distance is of the magnitude of hundreds of thousands of metres, then a difference of 23 m is very small and not significant for the car manufacturer's intended purpose of the measurement.

3. Thermometer B. Human body temperature of a healthy individual is always between 36.5°C–37.5°C, so any temperatures more than one or two degrees out of that range are not relevant. As the range is so small, a high degree of accuracy is needed in order to measure any fluctuation in temperature.

Worksheet E: Suggested answers

The following represents an example of possible points of discussion.

A1 and A2

(a) Each sample should contain the same quantity of apple for comparisons to be valid.
(b) Counting is easier and less time-consuming than measuring the same mass into two samples (strength for A1, weakness for A2) but the counted pieces might be different sizes and therefore the volume of apple in each sample wouldn't be exactly the same, reducing the validity of any comparisons made (weakness for A1, strength for A2).

B1 and B2

(a) For the enzyme to have maximum effect, you need to increase the number of cells that the enzyme can access.
(b) It is easier to cut the apple into the same-sized pieces than it is to measure the extent of crushing when mashing the apple into a pulp; if one sample is mashed more than another, this could impact on the results and make them invalid (strength for B2, weakness for B1). However, crushing the apple into a pulp ensures maximum exposure of apple cells to the enzyme (strength for B1, weakness for B2).

C1 and C2

(a) The purpose of the experiment is to quantify the effect of pectinase on the volume of juice collected, so pectinase has to be added (it is the dependent variable).
(b) Some juice is produced just by disrupting apple tissue so a sample incubated with pectinase is not enough to indicate how much *extra* juice is produced. Testing two samples, one with pectinase and one with distilled water (a control experiment) allows direct comparisons to be made; this will show how much *additional* juice is made due to the presence of pectinase (weakness for C1, strength for C2). Testing two samples involves twice as much work and is more time-consuming (strength for C1, weakness for C2).

D1 and D2

(a) The pectinase needs to be given sufficient time to act on pectin in order to break the cells apart and split open the cells.
(b) As the temperature increases, the rate of reaction catalysed by an enzyme increases, so long as the temperature does not exceed the enzyme's optimum. Therefore, warming the pectinase will produce measurable results more quickly (strength of D1, weakness of D2). However, a constant temperature in a water bath can be difficult to maintain if an electronic water bath is not available (weakness of D1, strength of D2).

E1 and E2

(a) Filtering is required to separate the juice from the pulp, so that the volume of juice produced can be measured.
(b) Passive filtration will not extract all the juice and takes a longer time (weakness of E1, strength of E2). Applying pressure extracts more juice but it is not easy to control the degree of squeezing, which could lead to invalid results if one sample was squeezed more than the other (strength of E1, weakness of E2).

Worksheet F: Suggested answers

1.

Could be appropriate	Definitely not appropriate
A or C have a large enough capacity for the likely volume of juice.	B and D have insufficient capacity for the likely volume of juice.

2. The most appropriate measuring cylinder to choose would be C because it has the smallest adequate volume, and the intervals between each graduation are larger and easier to distinguish when lining up the meniscus. Even though B and D have greater precision, their small capacities mean that the juice might overflow.

3. Any apple pulp left behind would reduce the volume of juice collected and with a small volume, such an error would be large relative to the difference in volumes being measured.

Worksheet I: Suggested answers

1. Write down any possible issues with the method and equipment used:

   Learners should develop their own ideas but possible issues that might be mentioned include:

   - If two different apples were used, one for each sample, the apples might have contained different quantities of juice to being with.
   - When pulp and juice was transferred to the filter funnels, some might have been left in the beaker, so some of the juice might not have been measured.
   - Some of the juice might have remained in the filter funnel, especially if it was not squeezed or if insufficient time was allowed for filtration; so again some of the juice may not have been measured. If it was squeezed, then difficult to control the pressure used to squeeze, which could invalidate the results.
   - Filtration might have been slow, could be improved by heating the samples in a water-bath.
   - The measuring cylinder might not have been the appropriate size, or could have used one that allowed the volume to be measured with a higher degree of accuracy.
   - If timing wasn't done accurately, the pectinase could have been incubated with the apple sample for longer than the planned time, impacting on the results.
   - If working individually, difficult to time and do tasks; better to work in pairs.

2. Record your results in the table.

   Learners' own volumes.

3. Observation about appearance of the apple juice in each sample:

   Learners should observe a colour and clarity difference in the different juice samples. This is because the control sample contains fragments of apple tissue that have not been fully broken down giving the juice a cloudy appearance. The pectinase has broken these fragments down in sample E, causing the juice to have a paler colour and a clearer appearance.

Worksheet J: Suggested answers

Instruction 1: … Make notes of any possible problems with the method and equipment used. Use the space below…

Learners should develop their own ideas but possible issues that might be mentioned include:

- If two different apples were used, one for each sample, the apples might have contained different quantities of juice to being with.
- When pulp and juice was transferred to the filter funnels, some might have been left in the beaker, so some of the juice might not have been measured.
- Some of the juice might have remained in the filter funnel, especially if it was not squeezed or if insufficient time was allowed for filtration; so again some of the juice may not have been measured. If it was squeezed, then difficult to control the pressure used to squeeze, which could invalidate the results.
- Filtration might have been slow, could be improved by heating the samples in a water-bath.
- The measuring cylinder might not have been the appropriate size, or could have used one that allowed the volume to be measured with a higher degree of accuracy.
- If timing wasn't done accurately, the pectinase could have been incubated with the apple sample for longer than the planned time, impacting on the results.
- If working individually, difficult to time and do tasks; better to work in pairs.

Instruction 2: … complete the ordering activity …The correct order of the steps is as follows.

1	Collect the equipment and set it up.	**10**	Immediately start the stop clock.
2	Cut pieces of apple about 5 mm × 5 mm in size.	**11**	Leave the apple samples for 20 minutes at room temperature.
3	Place the beaker on the balance and press the 'zero/tare' button to set the mass to zero.	**12**	Place a funnel into each of two measuring cylinders.
4	Add apple pieces to the beaker until there is 50 g (1 dp).	**13**	Put a coffee filter into each funnel.
5	Label one beaker 'C' (for control) and one 'E' (for enzyme).	**14**	Label one measuring cylinder 'E' and label the other 'C'.
6	Break up the apple pieces in each beaker using a glass rod.	**15**	After 20 minutes, completely empty the beakers into the funnels.
7	Cover each beaker with cling film.	**16**	Wait until there is no more juice dripping from either funnel. (This can take 10–15 minutes.)
8	Add 4 cm^3 of distilled water to the beaker labelled 'C', stir with the glass rod and re-cover with cling film.	**17**	Read off and record the volume in each measuring cylinder.

9	Add 4 cm^3 of pectinase solution to the beaker labelled 'E', stir with the glass rod and re-cover with cling film.	**18**	Calculate how much extra juice was obtained from the sample of apple by using pectinase solution.

Instruction 4: Record your results in the table provided.

Sample	Volume of apple juice collected / cm^3
C (without pectinase)	19
E (with pectinase)	32

What is different about the appearance of the juice in each sample? Why might this be?

Learners should observe a colour and clarity difference in the different juice samples. This is because the control sample contains fragments of apple tissue that have not been fully broken down giving the juice a cloudy appearance. The pectinase has broken these fragments down in sample E, causing the juice to have a paler colour and a clearer appearance.

Instruction 5: Calculate the difference in volume of juice produced by the two samples.

13 cm^3

Worksheet K: Suggested answers

1. Use the following formula to calculate the percentage increase in apple juice produced.

   Learners' own results. The percentage increase for the *Virtual experiment* is 68% (1 dp).

2. Use the class data to calculate a mean percentage increase.

   Learners' own results. The mean percentage increase for the *Virtual experiment* is 65% (1 dp).

3. Use your interpretation of the results to write a conclusion.

   Learners should use their own interpretations of the results to write a conclusion. Below is an exemplar conclusion.

   Using pectinase to extract apple juice from apple tissue produces a significantly larger volume of clearer juice (32 cm^3) compared to juice that is extracted from a similar sample of apple tissue without using pectinase (19 cm^3). This is supported by the class mean percentage increase of juice produced in the presence of pectinase, of 65%.

Worksheet L: Suggested answers

Exemplar answers to the questions include:

1. Why is it important to use the same mass of apple in each sample?

To make a valid comparison of the volume of juice produced with enzyme with the volume of juice produced without enzyme. Different sample sizes could give different volumes of juice.

2. Why do you need to cover the samples with cling film?

To reduce evaporation of water during incubation, which could alter the volume of juice available to measure.

3. Why do you need to use a control experiment?

A sample incubated with pectinase is not enough to indicate how much *extra* juice is produced by using enzyme. Testing two samples, one with pectinase and one with distilled water (a control experiment) allows direct comparisons to be made; this will show how much *additional* juice is made due to the presence of pectinase

4. Why do you need to stir the sample? Why do you need to use a clean glass rod?

Stirring mixes the enzyme and the water evenly in the sample. A clean glass rod is needed to avoid contaminating the control sample with enzyme from the other sample.

5. Why do you need to start the stop clock immediately? Why is pectinase added last? Why is the pectinase sample emptied into the filter first?

The enzyme will start to work as soon as the solution is added, so in order for the samples to be incubated for the same length of time, the pectinase must be added last, the timer started immediately and then be the first sample to be emptied.

6. Why do you need to leave **both** samples for the same amount of time at the same temperature?

To make a valid comparison of the volume of juice produced with enzyme with the volume of juice produced without enzyme. Different times or temperatures could give different volumes of juice.

7. Why is it important to completely empty both beakers?

Any apple pulp left behind would reduce the volume of juice collected and with a small volume, such an error would be large relative to the difference in volumes being measured.

Learners' evaluations and improvements will vary according to their experiments. Below is an exemplar evaluation.

The experiment is a valid test of the effectiveness of using an enzyme to extract juice from apple tissue because I used a control sample and as far as possible, I treated both samples of apple tissue in the same way, apart from adding pectinase to one of them. However, the method was time-consuming because the incubation and filtration both took a fairly long time, meaning that I did not have enough time to carry out repeats in one lesson. Pulping the apple tissue with a glass rod and making sure all the juice was filtered were tricky procedures and I found it difficult to make sure that they were carried out in exactly the same way for both samples. I used tissue from one apple for one sample and tissue from another apple for the second sample and the two apples may have contained different quantities of juice. When I transferred pulp and juice to the filter funnels I left some behind in the beaker, so I may not have measured all the juice. Some of the juice may have remained in the filter funnel because my filtration was a bit rushed and I did not squeeze it so some of the juice may not have been measured. Although there were some volume errors caused by these difficulties, I think that the percentage increase in juice obtained by using pectinase was still large enough for me to draw a confident conclusion.

Some of the problems could be solved by improving the method. If more than one apple is used for the samples, then the pieces should be mixed together before using them so that any differences in juice content of different apples is evened out. Emptying the beakers into the filter funnels could be done more thoroughly because I think this caused one of the largest errors in my volumes. Allowing more time for the all of the juice to filter through the filter paper would be another useful improvement. If the apple tissue samples were incubated in a warmer temperature, then a larger difference in juice volumes might be obtained in a shorter time, since the pectinase would be working closer to its optimum temperature. This would allow slightly more time for the filtration part of the method. Finally, repeats could possibly be done by processing three pairs of samples in batches. This would allow a mean value to be calculated, so any anomalous results could be identified.

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