Cambridge Assessment International Education

Teaching Pack

Investigating the effect of changing surface area-to-volume ratio on diffusion

Cambridge International AS & A Level

Biology 9700

Version 1

Cambridge Pathway

Contents

Icons used in this pack:


Briefing lesson


Planning lesson


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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 3 (Advanced Practical Skills) or Paper 5 (Planning, Analysis and Evaluation).

This is one of a range of *Teaching Packs* and each pack is based on one experiment. The packs can be used in any order to suit your teaching sequence.

The structure is as follows:

Briefing lesson (1 hour*)
This lesson reinforces the key concepts, relevant skills, knowledge and understanding linked to the experiment.

↓

Planning lesson (1 hour*)
This lesson focuses on planning an experiment.
It ends with a demonstration video of the experiment.

↓

Lab lesson (1 hour*)
This lesson focuses on carrying out the experiment including the collection and recording of observations, measurements and estimates.

↓

Debriefing lesson (1 hour*)
This lesson focuses on the analysis and interpretation of data.
This includes making conclusions, evaluating methods and the quality of data and how improvements could be made.

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

In this pack, you will find lesson plans, worksheets and teacher resource sheets.

Experiment: Investigating the effect of changing surface area-to-volume ratio on diffusion

This *Teaching Pack* focuses on an investigation into the effect of changing surface area-to-volume ratio on diffusion.

This investigation shows how varying the surface area to volume ratio of a cell affects the diffusion of a small molecule. The results of this investigation suggest why transport systems evolved in multicellular organisms.

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

- 4.2 Movement into and out of cells

The experiment covers the following experimental skills, as listed in **AO3: Experimental skills and investigations:**

- plan experiments and investigations
- collect, record and present observations, measurements and estimates
- analyse and interpret data to reach conclusions
- evaluate methods and quality of data and suggest improvements.

Prior knowledge

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

- 4.1 Fluid mosaic membranes
- 4.2 Movement into and out of cells

Briefing lesson: Cell dimensions

Resources	• Worksheets A and B • Teacher Instructions 1 • Poster paper • Adhesive tape or putty • String • Marker pens • Sticky notes

Learning objectives	By the end of the lesson: • **all learners** should be able to describe the structure and key properties of the cell surface membrane. • **most learners** should be able to explain how an immeasurable factor can be investigated indirectly by measuring another factor with which it is strongly correlated. • **some learners** will be able to evaluate models to explain how they represent a scientific concept.

Timings	Activity
10 min	**Starter/Introduction** Learners will know of the importance of surface area in organisms and its relationship to concepts such as the cell surface membrane, and methods by which molecules are transported into and out of cells. To reinforce key terms, encourage learners to ask '*What's the question?*' when given an answer. Use **Teacher Instructions 1** to run this activity, in which a range of single-word terms and simple sentences are provided. To extend the activity, challenge learners to suggest the most appropriate command terms for each question.
45 min	**Main lesson** Inform learners that in the upcoming practical lesson, they will investigate the effect of changing surface area-to-volume ratio on the rate of absorption by diffusion. Divide the class board into groups of 2-3. Provide each group with Worksheet A, which asks them '*why are cells so tiny?*' These questions build learners' confidence in calculating the surface area and volume of regular shapes and how the surface area-to-volume ratio reduces as an object grows larger. After 10 minutes, pair learners at random and ask them to read each other's work and discuss points on which they disagree, to promote a common class understanding. Provide Worksheet B to learners. This challenges learners to collaborate in small groups to prepare a poster illustrating the importance of surface area-to-volume ratio on the rate of exchange of materials with their environment. Some guidance (such as keeping text to a minimum and filling available space) will be necessary. At the end of the activity, host a 'marketplace' activity in which one member of each group stands by their poster and offers an explanation to other groups as they move around the room. Alternatively, learners could be asked to stick their work on the wall or hang it from a 'washing line' to display to others.

5 min	**Plenary** Host a short activity in which learners are challenged to compete with others to compare and contrast a series of terms relevant to this lesson. An example could be 'phospholipid, membrane protein, cholesterol.' All of these molecules have polar and non-polar portions; however, only one of them has peptide bonds (the membrane protein).

Planning lesson: Modelling organisms

Resources

- Worksheets C and D
- A block of agar stained with cresol red solution (made using an ice cube tray)
- 1 scalpel or sharp knife
- 1 100 cm^3 beaker
- 1 50 cm^3 measuring cylinder
- 50 cm^3 dilute hydrochloric acid (1.0 mol dm^{-3})
- 1 white tile
- 1 glass rod
- 1 stopclock
- 1 ruler (length 30cm, with mm graduations)
- 1 pair of tweezers
- paper towels
- gloves

Learning objectives

By the end of the lesson:

- **all learners** will be able to outline how a model can be used to investigate the effect of surface area-to-volume ratio on exchange rate.
- **most learners** will be able to describe how to investigate the effect of surface area-to-volume ratio on exchange rate.
- **some learners** will be able to explain how to modify an investigation into the effect of surface area-to-volume ratio on exchange rate.

Timings	Activity
20 min	**Starter/Introduction** Ask learners to gather around the teacher's table. Remind learners that they are going to plan an experiment to investigate the effect of surface area-to-volume ratio on exchange rate. With a knife, carefully cut a block of agar, stained with cresol red dye. Prepare at least 2-3 blocks of different dimensions. Ask learners to calculate the surface area and volume of these blocks, to remind them of their work last lesson. Then demonstrate how a block will gradually change colour to orange when it is placed into hydrochloric acid in a beaker. Elicit an understanding of how this could be used to investigate the relationship between the two variables. Share Worksheet C with learners. Challenge them to spend 5-10 minutes to prepare a brief outline of the basis of the investigation. They should use as many of the provided key words as possible.
30 min	**Main lesson** Hand out Worksheet D, which provides learners with a series of prompts regarding the planning of this investigation. Provide 10-15 minutes for learners to complete the exercise, and then challenge them to compare their choices with a neighbour and decide if any of their choices have changed in light of their discussions. Share with learners the answers to Worksheet D and discuss the method; then, provide Worksheet E, which includes a summary table.

	**Plenary** Ask learners to line along the wall of the classroom/ outside the classroom in the corridor. Assuming that there are an equal or greater number of learners than the number of steps in the method, walk past each learner in the line and as you do, each learner should, call out the step of the method or a safety precaution. Learners should be instructed to keep Worksheet D and Worksheet E safe and bring them to the upcoming *Lab lesson*.

Lab lesson: Getting practical

Resources	• Worksheet E • A block of agar stained with cresol red solution (made using an ice cube tray) • 1 scalpel or sharp knife • 1 100 cm^3 beaker • 1 50 cm^3 measuring cylinder • 50 cm^3 dilute hydrochloric acid (1.0 mol dm^{-3}) • 2 white tiles • 1 glass rod • 1 stopclock • 1 ruler (length 30cm, with mm graduations) • 1 pair of tweezers • 1 marker pen • paper towels • gloves

Learning objectives	By the end of the lesson: • **all learners** will be able to conduct an investigation into the relationship between the surface area-to-volume ratio of a model cell and the rate of diffusion. • **most learners** will be able to explain why specific steps are taken during an investigation into the relationship between the surface area-to-volume ratio of a model cell and the rate of diffusion. • **some learners** will be able to make suggestions to improve an investigation into the relationship between the surface area-to-volume ratio of a model cell and the rate of diffusion.

Timings	Activity
5 min	**Starter/Introduction** Check that learners have brought with them Worksheet E and Worksheet F, and reiterate some of the key messages from the previous lesson regarding best practice in this activity.
45 min	**Main lesson** Explain that as they conduct the investigation, they need to write down three problems they encounter and how they overcame them and to consider what kind of graph they should plot of their data. **Safety** 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.
10 min	**Plenary** Learners will be at different stages of the practical activity towards the end of the lesson, with some likely to need the full hour to completely finish. Provide graph paper and elicit that as the data is continuous, they should draw a line graph. Ask if the points should be joined by a series of straight lines, a smooth curve, or a

	line/curve of best fit and why. Some learners may need to undertake this section of the task for homework.

Teacher notes

Watch the video showing the investigation into the effect of changing surface area-to-volume ratio on diffusion (teacher version) and read these notes.

Each group will require:

- a block of agar stained with cresol red solution (made using an ice cube tray)*
- 1 scalpel or sharp knife
- 1 100 cm^3 beaker
- 1 50 cm^3 measuring cylinder
- 50 cm^3 dilute hydrochloric acid (1.0 mol dm^{-3})
- 2 white tiles
- 1 glass rod
- 1 stopclock
- 1 ruler (length 30cm, with mm graduations)
- 1 pair of tweezers
- 1 marker pen
- paper towels
- gloves

Safety

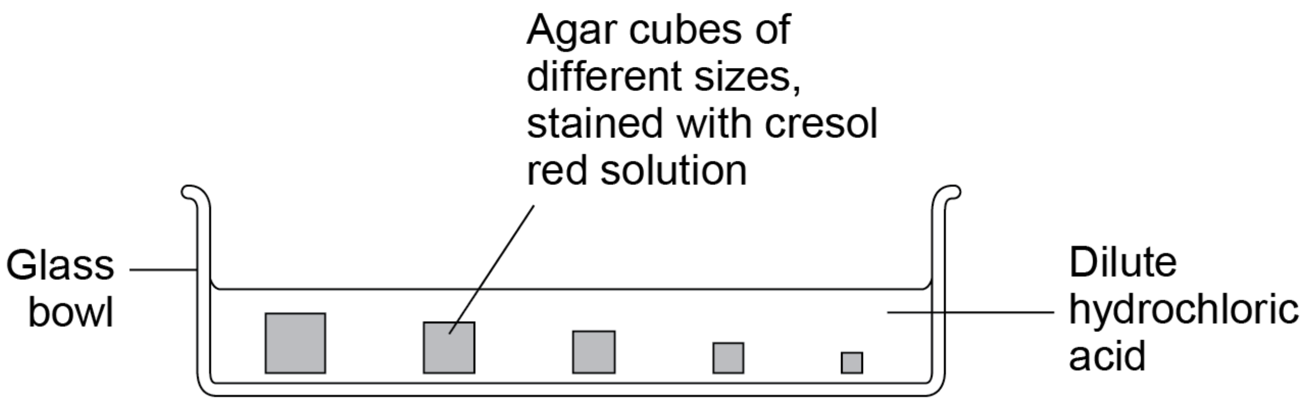
The information in the table below is a summary of the key points you should consider before undertaking this experiment with your learners.

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

Substance	Hazard	First aid
Cresol Red	 GHS08 (*health hazard* **HH**)  GHS07 (*moderate hazard* **MH**)  GHS09 (*hazardous to the aquatic environment* **N**)	**In the eye:** Flood the eye with gently-running tap water for at least 10 min. See a doctor. **Swallowed:** Do no more than wash out the mouth with water. Do **n**ot 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:** Remove contaminated clothing and rinse it. Wash off the skin with plenty of water. **Spilt on the floor, bench, etc.:** Wipe up small solution spills with cloth; for larger spills use mineral absorbent (e.g. cat litter).

Substance	Hazard	First aid
Hydrochloric acid (dilute)	 GHS07 (*moderate hazard* **MH**) [below a concentration of 2.7 mol/dm^3]	**In the eye:** Flood the eye with gently-running tap water for 10 min. See a doctor. **Vapour breathed in:** Remove to fresh air. Call a doctor if breathing is difficult. **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:** Remove contaminated clothing, then drench the skin with plenty of water. If a large area is affected or blistering occurs, see a doctor. **Spilt on the floor, bench, etc.:** For release of gas, consider the need to evacuate the lab and open all windows. For large spills, and especially for (moderately) concentrated acid, cover with mineral absorbent (e.g. cat litter) and scoop into a bucket. Neutralise with sodium carbonate. Rinse with plenty of water. Wipe up small amounts with a damp cloth and rinse it well.

Experiment set-up



Teacher method

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

Do not share this method with learners.

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.

Steps	Notes
1. Model cells of different sizes can be made by cutting cubes of agar of different sizes from a block of agar stained with cresol red.	*When dilute hydrochloric acid is added to cresol red solution, a chemical reaction occurs that changes the red colour to orange.*
2. Holding the scalpel blade vertical, the agar cube is trimmed to make it into a rectangular block.	*This removes any curved edges from the agar block.*
3. Five cubes are cut with a range of dimensions.	*Take care to precisely measure the lengths to ensure that they are of accurate size. These cubes represent cells of different sizes. The largest cube has the smallest surface area to volume ratio.*
4. Calculate the surface area to volume ratio of the cubes before the experiment begins	*Convert these figures into decimal numbers, which will be easier to plot on a graph.*
5. Place the agar cubes into a flat glass dish.	*The dish should be large enough to contain all five blocks without them needing to touch.*
6. Pour dilute hydrochloric acid into the dish and start the stopclock at the same time.	*The cubes should be completely submerged. A glass rod can be used to move them slightly inside the acid to ensure that they do not touch each other.*
7. Incubate the dish at room temperature.	*As the acid diffuses into the agar cubes, it reacts with the cresol red dye, which turns from red to orange.*
8. Record the time it takes for each cube to become completely orange.	*The larger the cube, the longer it will take for the red colour to disappear.*

9. Plot a graph of surface area to volume ratio against the time taken for the agar cube to turn completely orange.	*A decrease in the surface area to volume ratio is associated with a reduction in the rate of diffusion in the model cell.*

Debriefing lesson: Evaluation stations

Resources	• Worksheet G

Learning objectives	By the end of the lesson: • **all learners** will be able to state some uses of gel electrophoresis. • **most learners** will be able to describe how gel electrophoresis can be used. • **some learners** will be able to explain some of the problems that are associated with the use of gel electrophoresis.

Timings	Activity
15 min	**Starter/Introduction** Ask learners to retrieve their graphs and to compare their work with that of their partner. Encourage them to first *describe* the trend, and then *explain* the relationship they see. Ask for a few pairs of learners to offer their contributions to the class. Next, provide learners with Worksheet F. Encourage them to review their responses in light of this information.
40 min	**Main lesson** Learners should be asked to retrieve their tables of data (Worksheet E) and their graphs, which were plotted for homework. Ask them to form groups of 3-4 and then follow the instructions on Worksheet G. This asks them a series of questions on the validity of 'pooling' their data and calculating 95% confidence interval error bars on a piece of graph paper provided, as well as reflecting on the validity of the agar blocks as models of cells. As they work, circulate around the room to offer prompts and guidance. Through discussion, ask students to think back to their work on the need for transport systems. Discuss how the needs of mammals such as humans are likely to differ from those of plants, and why the type of transport system found in plants would not be adequate for an active mammal.
5 min	**Plenary** Prepare a passage that summarises the wide range of concepts that learners have encountered in this subtopic, in which 5-10 mistakes have been intentionally included. These could include spelling mistakes, but also conceptual errors. Discuss among the class. Examples are provided below. • *'Recording the time taken for agar blocks to completely change colour ten seconds too late each time would be a random error.'* • *'The blocks with the greatest surface area-to-volume ratio have the slowest rate of exchange.'* • *'A figure for the rate of a reaction can be obtained by multiplying the time taken by 1.'*

Worksheets and answers

Teacher instructions 1: What’s the question?

In this activity, pose questions ‘in reverse’ to learners. Give them a series of answers and then challenge them to suggest a question for which the answers could be given. This engages learners in higher-order thinking skills. To add an extra degree of challenge, ask learners to decide on the most appropriate command term (taken from the Syllabus) for each of their responses.

Examples should focus on the topics relevant to the upcoming topic, including the cell surface membrane and methods of transport. Three examples are provided below.

answer to provide to learners	suggested question	command word
phospholipid	*‘what is the most common molecule in the cell surface membrane?’*	***state***
particles move from a region of high concentration to a region of low concentration	*‘what happens during diffusion?’*	***define***
by active transport, using ATP from the mitochondria	*‘how does a cell absorb substances against the concentration gradient?’*	***explain***

Worksheet A: Why are cells so tiny?

Cells range in size from around 1 μm (a typical bacterial cell) to 100 μm (a human ovum). However, with some very unusual exceptions, cells are never much larger than this. In this investigation, you will explore why cells do not grow beyond a certain size.

The three cubes in **Figure 1** represent three representations of cells that have been enlarged.

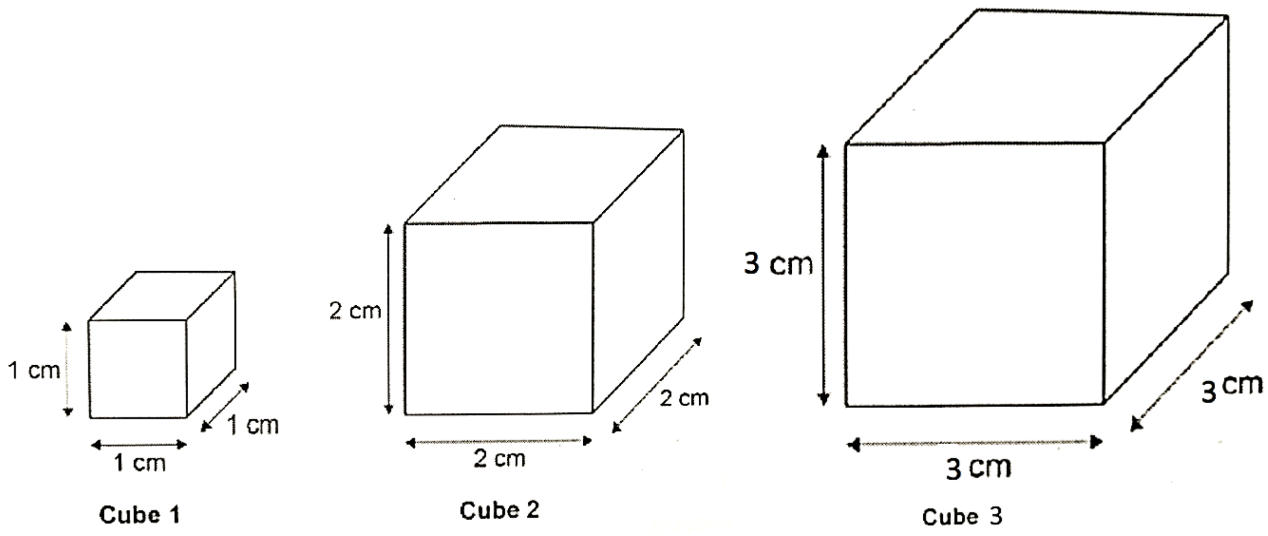


Figure 1: Models of three cells of different sizes.

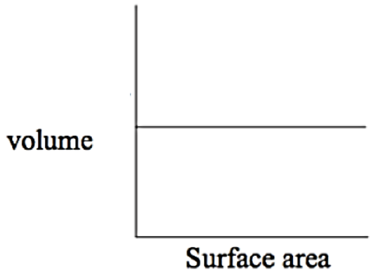
1. Complete the table below to find the surface area and the volume of each cell model. Two calculations have been done for you.

cube	surface area/ cm^2	Volume/ cm^3
1		1 x 1 x 1 = **1**
2	2 x 2 x 6 = **24**	
3		

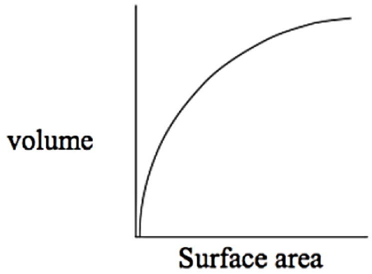
Worksheet A: Why are cells so tiny? *continued*

2. Using your calculations, choose the graph below that best represents the relationship between surface area and volume.

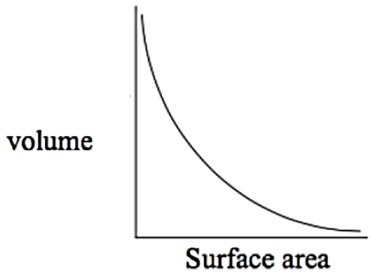
A.



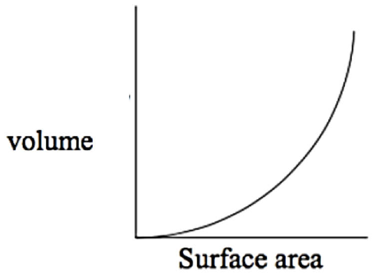
B.



C.



D.



Answer: __________

3. To investigate the rate of diffusion of substances between a cell and its environment, the surface area to volume ratio can be calculated using the following equation:

$$\text{surface area to volume ratio} = \frac{\text{surface area}}{\text{volume}}$$

Find the surface area to volume ratio of cubes 1, 2 and 3 in **Figure 1**. Note that this ratio has no units.

Cube 1: __________ Cube 2: __________ Cube 3: __________

4. Use the information in this activity to complete the following summary paragraph. Circle the correct word when you are provided with a choice of two.

As the size of a cell increases/ decreases, its surface area to volume ratio increases/ decreases. This is because the surface area increases/ decreases at a greater/ lesser rate than the volume as a cell becomes larger. Cells with a larger/ smaller surface area to volume ratio will be able to exchange materials with their environment more/ less quickly.

Worksheet B: Poster presentations

In this activity, you will work as a group to produce a poster. This poster should illustrate the importance of surface area-to-volume ratio on the rate of exchange of materials with their environment.

You have been provided with the following resources:

- Poster paper
- Marker pens
- Scissors
- Glue

Ensure that you include in your poster reference to:

- How different sized cells have different surface area-to-volume ratios.
- The mechanism of diffusion.
- Why transport systems evolved in multicellular organisms.

Your teacher will inform you how long you have to complete this activity. When this time has passed, you will be invited to display your work on the wall and receive feedback from other groups in your class.

Worksheet C: Modelling cells

The exchange of substances between a cell and its environment cannot be directly observed. However, it is possible to use models of cells with different surface area-to-volume ratios using agar gel coloured with an indicator.

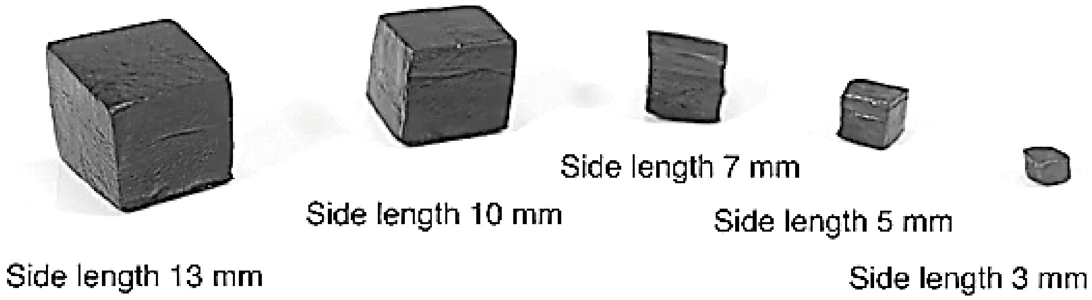


Figure 1: The sizes of agar-cresol red cubes used in this investigation

Note that cresol red is red in neutral or alkaline conditions, but orange in acidic conditions.

Using the information in the figure to help you, outline how you could investigate the effect of changing the surface area-to-volume ratio of the agar blocks (model cells) on the rate of diffusion of a substance into the agar block (model cell).

You should use as many of the following 6 terms as you can in your summary.

- agar
- cresol red
- hydrochloric acid
- diffusion
- red
- orange

Worksheet D: Justifying choices

For each step of the method in the table below, two options are provided. Cross out and tick the options you feel are best. Justify your choice.

Step	Option 1	Option 2	Justify your choice
1	Cut spherical blocks of agar stained with cresol red. ✗	Cut square blocks of agar stained with cresol red. ✓	The actual dimensions of a spherical block will be more difficult to determine
2	Five cubes are cut of a range of dimensions.	Three cubes are cut of a range of dimensions.	
3	The cubes are placed into a curved evaporating dish.	The cubes are placed into a large flat dish.	
4	Pour hydrochloric acid into the dish, all at once, and then start a stopclock.	Add hydrochloric acid to the dish, one drop at a time, and then start a stopclock.	
5	Allow the cubes to touch each other if they come into contact.	Use a glass rod to move the cubes away from each other if they touch.	
6	Stop the stopclock and restart it as each cube completely changes colour.	Record the time on the stopclock as each cube completely changes colour.	

Worksheet E: Data table

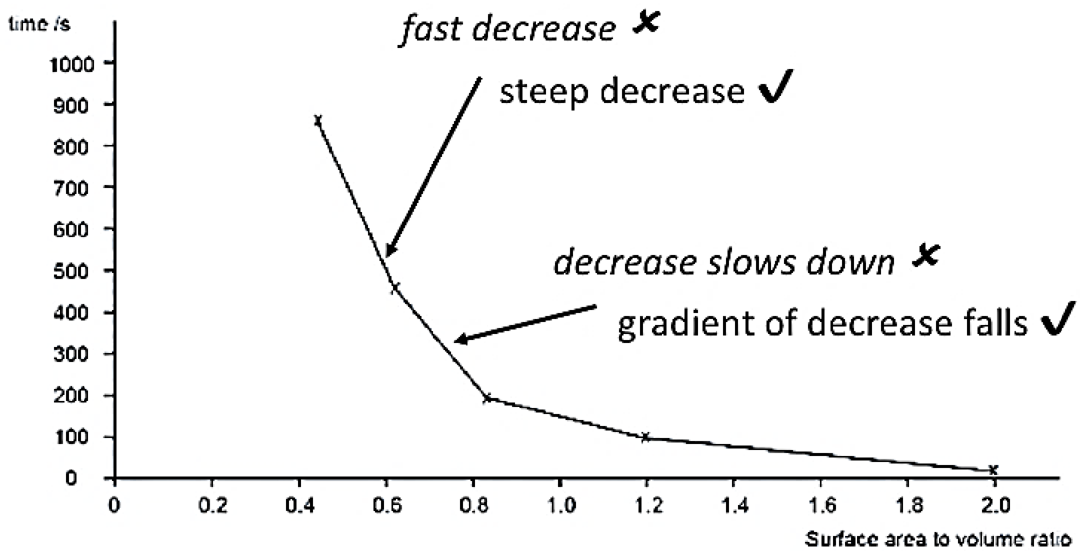
Cube side /mm	**Surface area /mm^2**	**Volume /mm^3**	**SA:vol ratio**	**Time taken to decolourise /s**
3	54	27	2.00	
5	150	125	1.20	
7	294	343	0.86	
10	600	1000	0.60	
13	1014	2197	0.46	

Worksheet F: Appropriate graphing

Use the following guidance to **plot a graph of surface area to volume ratio against the time taken to completely change colour**.

When **drawing** your graph, remember to:

- display the independent variable on the x-axis and the dependent variable on the y-axis
- use a small cross to mark each data point
- make sure the intersection of the crosses are exactly on the required point
- make sure the plotted points are connected with a clear, sharp straight line passing through each point (assuming that there are no anomalous points, which should be excluded)
- avoid extrapolating (extending) the curve beyond the plotted points
- draw the peak where it naturally falls on the curve rather than at the highest point



If you finish plotting your graph and still have time, consider the following points:

When **describing** a graph, remember to:

- avoid using the term 'because.'
- Identify specific sections of the plotted line to talk about by looking for changes in the gradient. Use terms such as 'however' to make comparisons.
- avoid referring to terms related to time, e.g. 'slow increase' and 'fast decrease' (see graph for 'dos' and 'don'ts').

When **explaining** the results in a graph, remember to:

- refer to the scientific basis of the changes you have described, by using terms such as 'because' and 'due to.'

Worksheet G: Discussing data

Your teacher will organise you into groups of 4 for this task.

The purpose of this task is to analyse the graph you have drawn. You will also need **Worksheet E**, on which you recorded your experimental data.

Firstly, you will assess each other's work using a checklist. Then you will calculate a mean for each of your cubes and use this to plot a graph together with 95% confidence interval error bars for each point.

TASK 1: Peer assessment
You should reserve 5 minutes for this task.

Swap your graph with the work of a partner. Use the checklist below to assess their work.

1. Is the graph a line graph? Yes ☐ No ☐
2. Is there a value at the origin of the graph? Yes ☐ No ☐
3. Is surface area-to-volume ratio on the x-axis and time on the y-axis? Yes ☐ No ☐
4. Are units been provided on the y-axis (for time), seconds? Yes ☐ No ☐
5. Are points plotted accurately with small crosses? Yes ☐ No ☐
6. Are points joined with straight lines? Yes ☐ No ☐

Provide feedback to your partner. Identify two features of their graph that they completed very well (select from the statements above for which you ticked 'yes'), but also identify a feature that could be improved (select from any statements for which you ticked 'no.')

TASK 2: Pooling data
You should reserve 15 minutes for this task.

At random, assign the following roles to each member of your group of four:

member	responsibility
mean calculator	use a calculator calculate the mean value of the time taken for the cube of each size to completely change colour
standard deviation calculator	use a spreadsheet to calculate the standard deviation of the time taken for the cube of each size to completely change colour
tabulator	draw a table to record the mean and standard deviation values, and leave a space to record the standard error and 95% CI values
graph plotter	draw a pair of axes identical to the graph you previously drew

Worksheet G: Discussing data *continued*

TASK 3: Evaluation stations
You should reserve 25 minutes for this task.

In your group, work through the following three tasks:

1. Why is the agar block a **poor** model of a cell? Make rough notes in your team.
Hint: think of the different ways in which substances move across the cell membrane.
2. Identify a source of error in this investigation and suggest a modification to the method that would improve the accuracy of the collected data. Record your thoughts.
3. Use the formula below to calculate the values of **standard error** and then the **95% confidence intervals (CI)** for each cube. See below for the equations you will need.

To calculate standard error, S_M:

$$S_M = \frac{s}{\sqrt{n}}$$

Where:

S_M = standard error
s = sample standard deviation
n = sample size

The standard error can be used to calculate the 95% confidence interval (CI) for a sample mean.

95% CI = ± 2 × SE

For a given sample mean, the error bar extends to the value of 95% CI either side of the sample mean.

Plot the mean values and the error bars on your team's graph. For which cube size was your team's data the most reliable? Which cube had the least reliable data?

When your teacher instructs you to, break up into four separate groups, joining together with members of the other groups of 4 that had the same roles in Task 2. Discuss your answers to these three questions and make summary notes to summarise these evaluations.

Worksheet A: Answers

1. The completed table is provided below.

cube	surface area/ cm^2	Volume/ cm^3
1	1 x 1 x 6 = **6**	1 x 1 x 1 = **1**
2	2 x 2 x 6 = **24**	2 x 2 x 2 = **8**
3	3 x 3 x 6 = **54**	3 x 3 x 3 = **27**

2. Answer: B

3. Cube A: 6:1 Cube B: 3:1 Cube C: 2:1

4. As the size of a cell increases/ ~~decreases~~, its surface area to volume ratio ~~increases~~/ decreases. This is because the surface area increases/ ~~decreases~~ at a ~~greater~~/ lesser rate than the volume as a cell becomes larger. Cells with a larger/ ~~smaller~~ surface area to volume ratio will be able to exchange materials with their environment ~~more~~/ less quickly.

Worksheet C: Answers

An example of a paragraph that summarises the basis of this investigation is as follows:

A range of agar cubes stained with cresol red are prepared of different sizes. These are model cells of different sizes. The time taken for the agar cube to completely change colour to orange, due to the diffusion of hydrochloric acid from the surroundings, can be measured and is proportional to the rate of exchange.

Worksheet D: Answers

Step	Option 1	Option 2	Justify your choice
1	Cut spherical blocks of agar stained with cresol red. ✗	Cut square blocks of agar stained with cresol red. ✓	The actual dimensions of a spherical block will be more difficult to determine
2	Five cubes are cut of a range of dimensions. ✓	Three cubes are cut of a range of dimensions. ✗	A greater number of cubes will allow for a more accurate trend to be identified
3	The cubes are placed into a curved evaporating dish. ✗	The cubes are placed into a flat dish. ✓	A flat dish will minimise the chance that the agar cubes will touch each other.
4	Pour hydrochloric acid into the dish, all at once, and then start a stopclock. ✓	Add hydrochloric acid to the dish, one drop at a time, and then start a stopclock. ✗	The exposure of all cubes to the acid at the same time means that a valid comparison can be made.
5	Allow the cubes to touch each other if they come into contact. ✗	Use a glass rod to move the cubes away from each other if they touch. ✓	All sides of the cubes should be in contact with the acid, so that the molecules can freely diffuse into the agar.
6	Stop the stopclock and restart it as each cube completely changes colour. ✗	Record the time on the stopclock as each cube completely changes colour. ✓	The measurement of time will be more accurate if the stopclock is allowed to run uninterrupted.

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