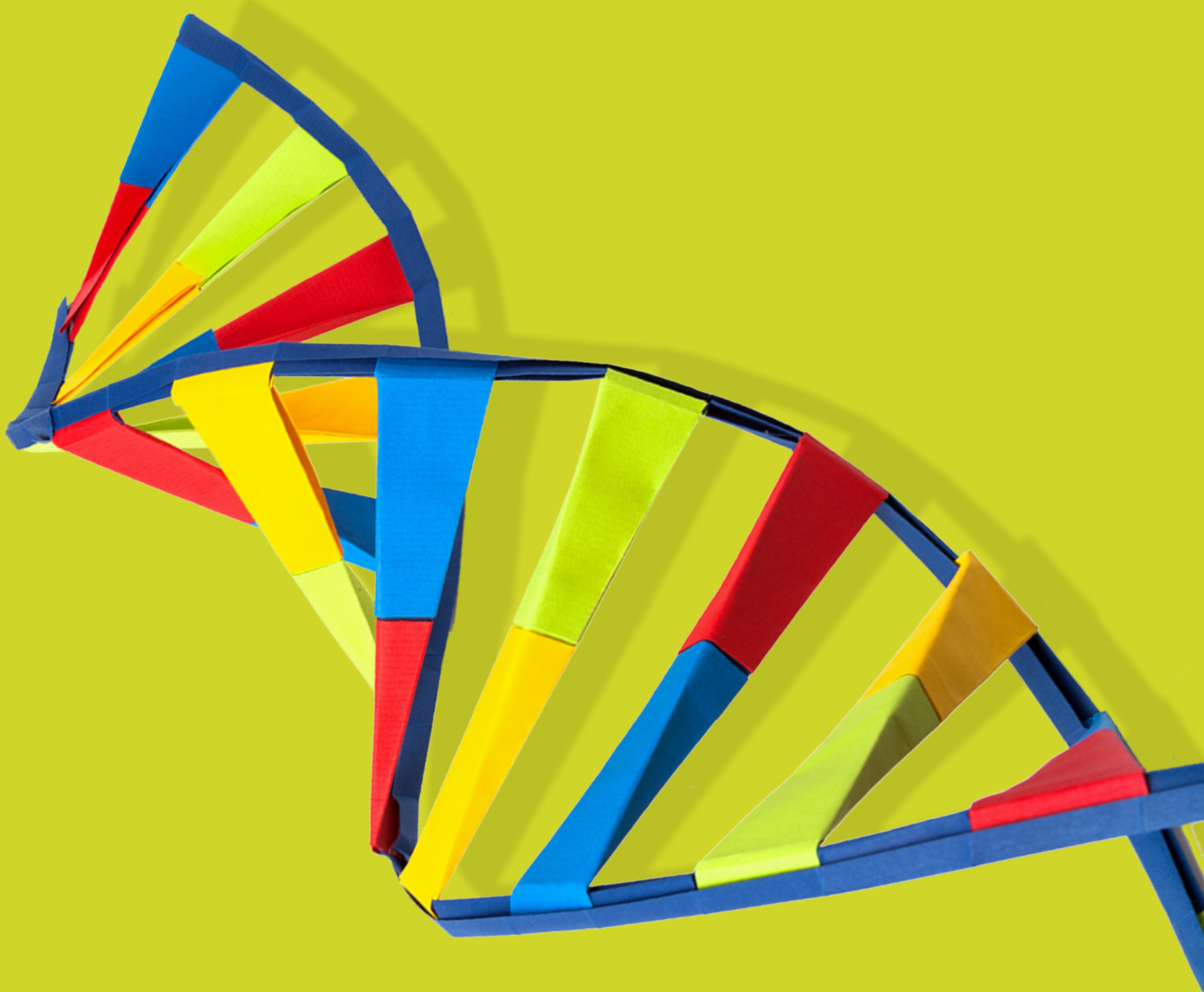


Teacher Guide iPDF Core Practicals GCSE Biology



GCSE (9–1) Sciences

Pearson Edexcel Level 1/Level 2 GCSE (9–1) Sciences

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Key

PRACTICALS SHOWN IN BOLD ARE THE ADDITIONAL PRACTICALS REQUIRED FOR GCSE BIOLOGY.

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Introduction

Purpose of this guide

This guide is designed to support you in delivering the core practicals for Edexcel. The following pages, for *each* core practical, will:

- Give you links to the specification content and highlight key areas to further your students' understanding.
- Contain key questions you can ask to focus your students, and get them thinking about why they are carrying out a particular practical in a certain way.
- Give you a sample question (where possible), with commentary relating to the assessment, which can be used as practice to consolidate students' understanding.

Changes to practical requirements in reformed GCSEs

There will not be any coursework in the GCSE (9–1) Science qualifications. Assessment of practical work is now included as part of the final exam, and a minimum of 15% of the total marks must be allocated to questions related to practical. In our exams, we will have questions on the core practicals in our specifications, as well as other questions on practicals related to the core practicals or techniques that students should be familiar with from their studies.

As well as the practical requirement, there is a list of apparatus and techniques that has been set out by the Department for Education (*Appendix 1*). Specifications must give students opportunities to cover the relevant apparatus and techniques, and this list has been mapped to our core practicals to show you how we are covering all of the requirements. As long as you carry out all of the core practicals, you will automatically cover the apparatus and techniques list. If you want to see how our core practicals map to this list, it is mapped (along with maths skills) in *Appendix 2*.

Approach to core practicals

In order to meet the requirements set out by Ofqual, you need to ensure your centre confirms that reasonable steps have been taken to secure that each learner has completed the practical activities set by us, and has made a contemporaneous record of the practical work and knowledge, skills and understanding derived from those practical activities.

The purpose of this statement is to ensure that practical work remains an important part of GCSE Science. In your day-to-day teaching, this just means that you need to ensure you cover the core practicals outlined by us and that your students are recording the work that they are doing as part of carrying out the core practicals. In practice, this could just be completing worksheets, taking results and doing some analysis or writing notes in their exercise books as a follow up to carrying out the practical. If you prefer, you can use a separate lab book for practical work, but this is not necessary. Indeed, as students will be required to have knowledge of these practical techniques and procedures for the final exam, it may be better to have this practical work sit alongside the relevant theoretical knowledge.

It is important to note that the approach to covering core practicals should be the same approach as you currently take to practical work in your science lessons. If you occasionally cover particular techniques as a carousel, or split students into groups to take readings, there is no reason why you cannot still do this—as long as you have taken reasonable steps to ensure your students all acquire experience of carrying out that particular procedure or technique.



Assessment of practical work

As a centre, you need to confirm that you have taken reasonable steps to ensure that each student has completed the compulsory core practicals and that the evidence for this is recorded. The practical record must include the knowledge, skills and understanding which that student has derived from those practical activities. To confirm that this has been done, centres must complete and submit an *authentication sheet* to confirm that all students have completed these core practicals. This authentication sheet can be found as an appendix in the specifications.

By signing this authentication sheet, you are confirming that reasonable steps have been taken to ensure that all students have been given the opportunity to carry out the core practicals outlined in the specifications. If students are ill or miss core practicals for any reason beyond the school's control, it does not require you to run catch up sessions for those individual students.

In exam papers, practical work will be assessed across the assessment objectives. The sample questions included in this core practical guide outline how you can use that question to consolidate your students' understanding of that particular core practical. The exam papers will assess student's understanding of the practical work, and they will be at an advantage if they have carried out all the core practicals in the course.

Maths skills

Practical activities offer a wide range of opportunities to cover particular mathematical skills. As part of this guide, we have outlined where there are good opportunities to cover mathematical techniques as part of each core practical. There is also a mapping in *Appendix 2* which maps the maths skills outlined by the DfE to the relevant core practical.

Note: There is a Guide to Maths for Scientists which you can download from the Edexcel website. This guide outlines the content that students will have covered in their maths lessons throughout KS3 and KS4. You can use this guide to help you understand how different areas are approached in maths, and therefore support your teaching of mathematical content in science lessons.



Biology

There are six core practicals in the biology section of GCSE Combined Science. GCSE Biology covers the same six practicals as well as an additional two, to make up eight core practicals in total.

This biology section outlines each core practical and gives a brief description of each one. The final part goes through each core practical in turn and outlines key skills as well as an extract of a sample exam question which links to the core practical.

Core practical descriptions

Note: 1.13B and 5.18B are separate GCSE Biology only.

Core practical		Description
1.6	<i>Investigate biological specimens using microscopes including magnification calculations and labelled scientific drawings from observations</i>	This practical allows students to develop their skills in using a light microscope, preparing slides, and producing labelled scientific drawings. Students need to be familiar with the set-up and use of a light microscope, as well as to be able to identify structures that they see. Magnification calculations will also be required.
1.10	<i>Investigate the effect of pH on enzyme activity</i>	For this core practical students will investigate the effect of pH, however other variables can also be investigated to enhance practical work in this area. This method uses amylase (in solutions of different pH) to break down starch. The reaction can be monitored by using iodine to test the presence of starch in the solution with a continuous sampling method. To maintain the temperature of the solution, a Bunsen burner and water beaker must be used.
1.13B	<i>Investigate the use of chemical reagents to identify starch, reducing sugars, proteins and fats</i>	Carry out food tests shown below: 1. identify starch by using iodine solution 2. identify reducing sugars using Benedict's solution (and a water bath) 3. identify protein using the Biuret test (adding potassium hydroxide to a solution of the food, followed by copper sulfate) 4. identify fats and oils (lipids) using the emulsion test to show the formation of a precipitate
1.16	<i>Investigate osmosis in potatoes</i>	A known mass of potato must be added to sucrose solution, left for some time, and the final mass recorded to obtain the percentage change in mass. This investigation looks at the exchange of water between the potato and solution and allows the concentration of sucrose in the potato to be determined. The practical provides an opportunity for the appreciation of the need to control variables.



5.18B	<i>Investigate the effects of antiseptics, antibiotics or plant extracts on microbial cultures</i>	This practical provides the opportunity for learners to carry out aseptic techniques (Biology statement 5.17). Petri dishes pre-poured with agar must be inoculated with bacteria and discs of antiseptic/antibiotics/plant extracts can be used to determine their effect on bacterial growth. Sterile aseptic technique must include the use of a Bunsen burner.
6.5	<i>Investigate the effect of light intensity on the rate of photosynthesis</i>	Algal balls (or similar) must be set up and placed at varying distances from a light source to investigate the effect of light intensity on the rate of photosynthesis. The rate must be measured and compared to the distance away from the light source.
8.11	<i>Investigate the rate of respiration in living organisms</i>	Use of a simple respirometer to measure the effect of temperature on the oxygen consumption of some small organisms. A simple respirometer can be made using a tube with soda lime, cotton wool and organisms with a capillary tube to coloured liquid. Students can then track the progress of the liquid up the capillary tube over a set time. This experiment must be carried out using a water bath set at different temperatures. Safety and ethical considerations must also be covered.
9.5	<i>Investigate the relationship between organisms and their environment using field-work techniques, including quadrats and belt transects</i>	This investigation involves the use of a belt transect along a gradient (e.g. shaded area to an area with no shade). It involves students thinking about how to sample their chosen area, including the identification and observation of plants/organisms.



Core practical 1: Looking at cells

1.6 *Core practical: Investigate biological specimens using microscopes, including magnification calculations and labelled scientific drawings from observations*

Links to the specification content

- 1.3 Explain how changes in microscope technology, including electron microscopy, have enabled us to see cell structures with more clarity and detail than in the past and increased our understanding of the role of sub-cellular structures
- 1.4 Demonstrate an understanding of number, size and scale, including the use of estimations and explain when they should be used.
- 1.5 Demonstrate an understanding of the relationship between quantitative units in relation to cells, including:
 - a milli (10^{-3})
 - b micro (10^{-6})
 - c nano (10^{-9})
 - d pico (10^{-12})
 - e calculations with numbers written in standard form**

Introducing the practical

This core practical provides the opportunity for students to develop their skills in the use of a light microscope, the preparation of slides and the production of labelled scientific drawings from their observations. It then provides a context for the teaching and understanding of the associated maths skills including magnification calculations, the use of estimations and the relationship between quantitative units. For higher tier candidates, there is the opportunity to practice calculations using standard form. A comparison of observations made using a light microscope with images taken using an electron microscope also demonstrates how improvements in microscope technology have increased our understanding of sub-cellular structures.

Although students are likely to have used microscopes at Key Stage 3, it is a technical skill that they find difficult. It might be worth spending time practicing the basic skills needed to focus the microscope before attempting the core practical, either as a starter or in a previous lesson. The core practical suggests a range of cell types which can be used and students only need to look at a plant cell and an animal cell as a minimum. Students should understand the basic principles involved in the preparation of slides for use with a light microscope including the role of staining. Having prepared a slide, they must understand how to use the light microscope to focus in the specimen. They need to understand the total magnification produced by the eyepiece and objective lens and the mathematical relationship between magnification, image size and actual size. The sole use of pre-prepared slides will be insufficient to meet the demand of the core practical, but it does provide the opportunity for students to practice using a microscope and refine their skills for scientific drawings.

Link to GCSE Science 2011: 1.5 'Demonstrate an understanding of how changes in microscope technology have enabled us to see cells with more clarity and detail than in the past, including simple magnification calculations.' From B2 Topic 1 The building blocks of cells.



Investigating biological specimens

Questions you could ask to enhance learning and focus your students on important aspects of the practical:

- What sub-cellular structures are likely to be observed using a light microscope?
- Why are some sub-cellular structures not visible using a light microscope?
- What precautions are needed when preparing a microscope slide?
- Why should samples of animal cells be disposed of in disinfectant?
- Why does the layer of specimen cells need to be thin?
- Why do we stain the specimen cells?
- Why does the coverslip have to be carefully applied?
- What is the highest magnification for the light microscope?
- How is the focusing wheel used?
- When should the fine focusing wheel be used?
- What is a field of view and how can its size be measured?
- How is the actual size of a cell structure determined from microscope measurements?
- How can more detail be observed in cells?
- What are the important features of a drawing made from observations?

Skills that are covered in the practical:

- The preparation of microscope slides
- The importance of staining a specimen
- The ability to use a microscope to make observations
- The drawing of observations of specimens from a light microscope
- Magnification calculations from observations

Maths skills:

- Calculations of total magnification
- The mathematical relationship between magnification, image size and actual size
- Make estimations of size
- Understanding of scale and the relationship between different quantitative units (e.g millimetres, micrometres and nanometres)
- Calculations using numbers in standard form for higher tier candidates only



Your teacher may watch to see if you can:

- handle microscopes and slides carefully and safely.

Aim

To use a microscope to observe cells and sub-cellular structures.

Method 1: Examining pre-prepared slides of cells

Apparatus

- light microscope
- lamp
- prepared slides
- transparent ruler



Safety

Handle slides with care.

- Set up your microscope on the lowest magnification objective lens. Work out the total magnification and measure the diameter of the **field of view** (by using the microscope to observe a transparent ruler).
- Put the next most powerful objective lens in place. Work out the magnification and by how much it has increased from the magnification in step A (e.g. moving from a $\times 10$ to a $\times 50$ is an increase of 5 times). Now divide the diameter of the field of view from step A by the increase in magnification to give you the new diameter of the field of view (e.g. if the field of view in step A was 2 mm, then $2 \div 5 = 0.4$ mm). Do this for each objective lens. Record the total magnification and field of view diameter for each objective lens.
- Now go back to the lowest magnification objective lens and observe a prepared slide.
- Use higher magnifications to observe the cells. Estimate the sizes using your field of view diameters.
- Identify the cell parts. Have a look for **mitochondria** (you may not find any as they are very difficult to see).

Method 2: Examining your cheek cells

Apparatus

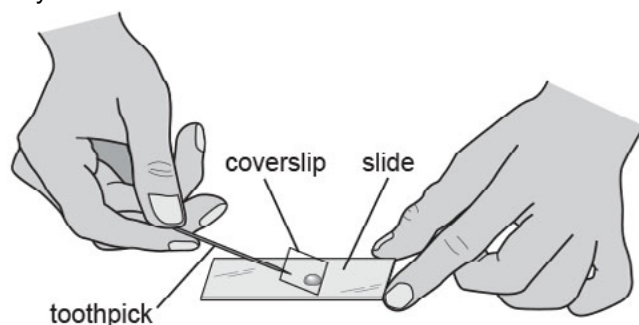
- light microscope
- lamp
- microscope slide
- coverslip
- methylene blue stain
- pipette
- paper towel
- water
- gloves
- wooden toothpick/ cocktail stick
- sterile wooden spatula/tongue depressor
- disinfectant



Safety

Handle slides with care. Anything that you have put into your mouth should be placed in disinfectant after use. Wear gloves if using stains. Wear eye protection.

- Using the pipette, add a small drop of water to the slide.
- Stroke the inside of your cheek gently with the wooden spatula. You only want to collect loose cells, so do not scratch the inside of your mouth.
- Use the end of the spatula that has been in your mouth to stir the drop of water on the slide. Place the used spatula in disinfectant.
- Put on gloves and use a pipette to add a small drop of methylene blue stain. This makes cells easier to see.
- Place a coverslip onto the slide at a 45° angle on one edge of the drop. Then use a toothpick to gently lower the coverslip down onto the drop, as shown in the diagram on the right. Avoid trapping air bubbles, which appear as black-edged circles under a microscope.
- Touch a piece of paper towel to any liquid that spreads out from under the coverslip.
- Use the lowest magnification objective lens to observe the slide. The **nuclei** of the cheek cells will be dark blue.
- Use higher magnifications to observe the cells. Estimate the sizes using your field of view diameters.
- Identify the cell parts. Have a look for mitochondria (you may not find any as they are very difficult to see).





Sciences Bio Core Prac 1 Looking at cells

Method 3: Examining onion or rhubarb stem cells

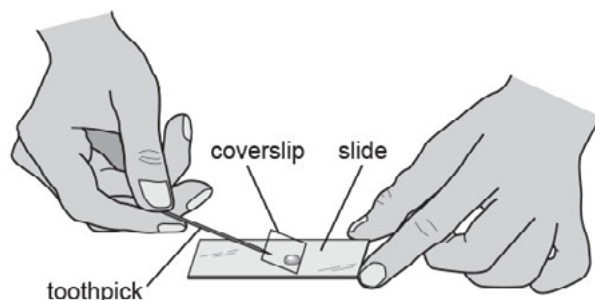
Apparatus

- light microscope
- lamp
- microscope slide
- coverslip
- iodine stain
- pipette
- paper towel
- water
- forceps
- wooden toothpick
- piece of onion bulb or rhubarb stem
- gloves

Safety

Handle slides and microscopes with care.
Wear gloves if using stains.
Wear eye protection.

- A** If you are going to look at onion cells, put on gloves and use a pipette to add a drop of iodine solution to a microscope slide. If you are going to look at rhubarb, add a drop of water to a microscope slide.
- B** Using forceps, remove a very small piece of the thin 'skin' on the inside of the fleshy part of the onion. It is very thin indeed and quite tricky to handle. Or remove a thin piece of red 'skin' from a rhubarb stem.
- C** Place the small piece of skin on the drop on the slide.
- D** Place a coverslip onto the slide at a 45° angle on one edge of the drop. Then use a toothpick to gently lower the coverslip down onto the drop, as shown in the diagram on the right. Avoid trapping air bubbles, which appear as black-edged circles under a microscope.
- E** Touch a piece of paper towel to any liquid that spreads out from under the coverslip.
- F** Use the lowest magnification objective lens to observe the slide. Then use higher magnifications to observe the cells in more detail. Estimate sizes as you observe.
- G** Identify the cell parts. Have a look for mitochondria (you may not find any as they are very difficult to see).



Method 4: Examining pondweed

Apparatus

- light microscope
- lamp
- microscope slide
- coverslip
- iodine stain
- pipette
- paper towel
- water
- forceps
- wooden toothpick
- piece of pondweed

Safety

Handle slides and microscopes with care.
Wear eye protection.

- A** Tear off a very small piece of pondweed leaf; a square with sides of up to 2 mm.
- B** Place the leaf sample onto a microscope slide and add a drop of water.
- C** Place a coverslip onto the slide at a 45° angle on one edge of the drop. Then use a toothpick to gently lower the coverslip down onto the drop, as shown in the diagram above. Avoid trapping air bubbles, which appear as black-edged circles under a microscope.
- D** Touch a piece of paper towel to any liquid that spreads out from under the coverslip.
- E** Use the lowest magnification objective lens to observe the slide.
- F** Use higher magnifications to observe the cells in more detail. Estimate sizes as you observe.
- G** Identify the cell parts. If you watch very carefully when you have the cells under a high magnification, you may well see the chloroplasts moving as the cytoplasm moves inside the cells.

Recording your results

- 1 Make a drawing of each type of cell that you examine. Label the parts and record the magnification.
- 2 Label the cells and their parts with any sizes that you have estimated using the diameter of the field of view.



Objectives

- B1.1** Explain how the sub-cellular structures of eukaryotic and prokaryotic cells are related to their functions, including:
- (a) animal cells – nucleus, cell membrane, mitochondria and ribosomes
 - (b) plant cells – nucleus, cell membrane, cell wall, chloroplasts, mitochondria and ribosomes.
- B1.4** Demonstrate an understanding of number, size and scale, including the use of estimations and explain when they should be used.
- B1.6** *Investigate biological specimens using microscopes, including magnification calculations and labelled scientific drawings from observations.*

Maths requirements

- 1d** Make estimates of the results of simple calculations, without using a calculator.
- 2h** Make order of magnitude calculations.

Learning outcomes

-  **SB1.1** Identify the parts of plant and animal cells.
-  **SB1.1** Recall the parts of plant and animal cells.
-  **SB1.1, SB1.6** Make drawings of plant and animal cells using a light microscope and identify their parts.
-  **SB1.1** Describe the functions of the sub-cellular structures commonly found in eukaryotic cells (nucleus, cell membrane, cell wall, chloroplasts, mitochondria and ribosomes).
-  **SB1.4** Estimate sizes using microscope fields of view.
-  **SB1.4** Estimate sizes using scale bars.

Exploring

1. Examining plant and animal cells – core practical

Students use Students' sheet CP1(Looking at cells) to look at simple animal and/or plant cells and identify their component parts. The first page of the worksheet looks at animal cells; students can use pre-prepared cells (Method 1) or prepare slides of their own cheek cells (Method 2). The second page of the worksheet gives various options for examining plant cells (Methods 3 and 4). The worksheet suggests a range of cell types that can be used. There is no requirement to cover all the cell types given on the worksheet, but students must prepare their own slides, use a microscope, calculate magnifications and make drawings of their observations.

It is recommend that all students do steps A and B of Method 1 to begin with, whatever cells they are then going on to observe. This will allow students to refresh their memories on microscope use, particularly those who have missed the work in the previous topic, and Skills Sheet UE 3 can be used to support this. These two steps at the start of Method 1 will also give students the opportunity to perform magnification calculations and measure the different fields of view that they will later use to observe cells. Skills Sheet UE 4 can be used to provide help with fields of view. When students are making their own slides, it is worth demonstrating what they need to do beforehand. Skills Sheet UE 2 can be used to support this.

Students should make drawings of their observations and add appropriate labels.

For demonstration, it is worth showing some pre-prepared cells in which mitochondria show up. These can be bought commercially or you can make your own using methylene blue – basic fuchsin stain, although the staining procedure (freely available on the Internet) is quite involved.



Support: Have an appropriate micrograph of human cheek cells/onion cells/rhubarb cells/*Elodea* cells on the board to help students identify the cells under the microscope and label them appropriately. You may need to give them the magnification. Help students with field of view measurements by giving them the sizes of the fields of view with the different objective lenses (or omit field of view work with very weak students). The diameters of the fields of view between different objective lenses are proportional, and so if you know the field of view with the low power objective you can work out the fields of view with the more powerful objective lenses. For example, if the total magnification using the lowest power objective is $\times 20$ and using the next most powerful objective gives a total of $\times 100$, the conversion factor between them is $100/20 = 5$. That is to say, the diameter of this field of view is 5 times smaller than the diameter of the lowest power objective field of view.

Stretch: Encourage students to complete as many of the different cell types as possible, and to add scale bars to their drawings.

Safety

Wear eye protection. Do not allow students to angle microscope mirrors towards the Sun, as this can seriously damage eyesight. Students should not eat the onion or rhubarb. Students should take care not to cut themselves when using glass slides. The use of one arm of a pair of forceps or a cocktail stick is preferred for lowering coverslips, rather than the use of mounted needles. Students should wear gloves if working with stains. Anything that has been in the mouths of students needs to be placed in disinfectant after use.

Expected results

Students should identify, draw and label cells and their parts. It is likely that they will not be able to see mitochondria, even on the highest magnification, although they may see small granules within the cytoplasm that may be a range of things depending on the cell type.

Course resources

Students' sheet CP1

Equipment

microscope, sterile (autoclaved) wooden spatulas/tongue depressors, access to beaker of 1% Virkon in which to dispose of used spatulas/tongue depressors, selection of pre-prepared slides of plant and animal cells (e.g. cheek cells, epithelial cells, palisade cells), plant material (e.g. onion, rhubarb and/or *Elodea* – decide before the practical whether to provide one tissue types for all students or to provide a range so that some or all students have the opportunity to observe different types of plant cells), stain (e.g. methylene blue, iodine solution), paper towel, gloves, plain glass microscope slide, coverslip, pipette, water



Sample question

These examples are taken from the sample assessment material. It is a mix of questions from 1BIO/1F and 1BIO/1H which illustrate a range of questions applicable to this core practical and the skills associated with it. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

A student wanted to observe dividing cells under a microscope.

The student squashed the root tip of an onion plant on a microscope slide.

- (c) (i) Describe how the student should use a light microscope to view the squashed root tip.

(3)

Question number	Answer	Mark
5(c)(i)	An answer that combines knowledge (1 mark) and understanding (2 marks) to provide a logical description: - place the slide on the stage of the microscope and look through the eyepiece lens (1) Plus two from: - turning the focusing wheel/knob will obtain a clear image (when looking through the eyepiece lens) (1) - start by using the lowest objective lens magnification (1) - increase the magnification of the objective lens and refocus (1)	(3)

Part (c)(i) is a question where students have to apply their knowledge on the technique of using a microscope which they obtained by completing the core practical.



- (ii) Even though the slide was at the correct magnification, the student could not see the chromosomes in the dividing cells.

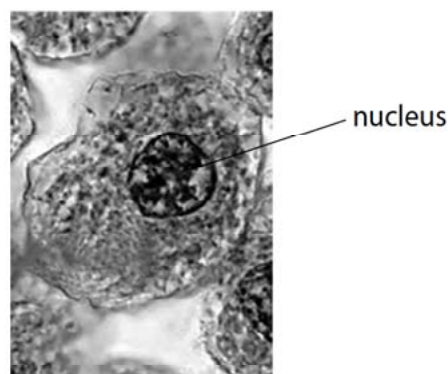
State what could be done to the slide to make the chromosomes more visible.

(1)

Question number	Answer	Mark
(c)(ii)	Use a stain (1)	(1)

Part (c)(ii) asks students to recognise the role of staining specimens to make cell structures more visible.

Figure 7 shows an image of an animal cell taken using a microscope with a 10× eyepiece lens and a 40× objective lens.



(Source: © Ed Reschke/Getty Images)

Figure 7

- (b) (i) The total magnification of the animal cell is

(1)

- ☐ A ×50
- ☐ B ×140
- ☐ C ×400
- ☐ D ×4000

Question number	Answer	Mark
4(b)(i)	C	(1)

Part (b)(i) is a question asking students to use their knowledge of a microscope to calculate the total magnification obtained by the combination of the eyepiece and objective lens.



(ii) The diameter of the cell is $15\text{ }\mu\text{m}$.

Use Figure 7 to estimate the diameter of the cell nucleus.

(1)

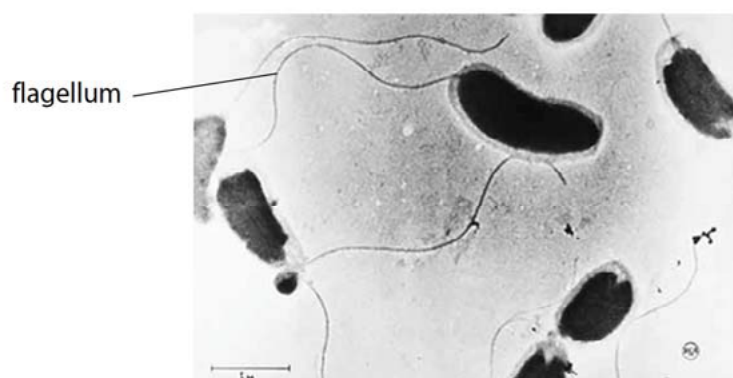
diameter of nucleus = μm

Question number	Answer	Additional guidance	Mark
4(b)(ii)	$5\text{ }\mu\text{m} \pm 1.5$	approximately a third of the diameter of the cell	(1)

Part (b)(ii) is a question that asks students to apply their knowledge on making estimations to an image. It does not require a magnification calculation.



(c) Figure 7 shows some *Vibrio cholerae*, the bacteria that cause cholera.



Magnification $\times 8000$

(Source: Corbis)

Figure 7

The length of one flagellum on Figure 7 is 68 mm.

Calculate the length of the flagellum in μm .

(3)

..... μm

(Total for Question 5 = 9 marks)

Question number	Answer	Additional guidance	Mark
5(c)	• $68 \div 8000$ (1) • 0.0085 (1) • $8.5 (\mu\text{m})$ (1)	award full marks for correct numerical answer without working	(3)

Part (c) is a question that combines the maths skills of a magnification calculation with the quantitative relationship between micrometres and millimetres.



Core practical 2: pH and Enzyme activity

1.10 Core practical: Investigate the effect of pH on enzyme activity

Links to the specification content

- | | |
|------|--|
| 1.7 | Explain the mechanism of enzyme action including the active site and enzyme specificity |
| 1.8 | Explain how enzymes can be denatured due to changes in the shape of the active site |
| 1.9 | Explain the effects of temperature, substrate concentration and pH on enzyme activity |
| 1.11 | Demonstrate an understanding of rate calculations for enzyme activity |
| 1.12 | Explain the importance of enzymes as biological catalysts in the synthesis of carbohydrates, proteins and lipids and their breakdown into sugars, amino acids and fatty acids and glycerol |

Introducing the practical

There are many factors which affect the activity of enzymes. The core practical focuses on pH, but there is also a suggested practical on the effect of substrate concentration on enzyme activity, which could be used to enhance learning. In addition, there is some information about a demonstration that can be used to demonstrate the calculation of the initial rate of enzyme action.

The core practical which looks at how pH affects the breakdown of starch using amylase has two knowledge aspects to it, enzyme activity and the breakdown of starch into smaller sugars. It also covers the use of iodine to identify the biological molecular starch, which is a biology-only specification point. Candidates may have completed variations on this practical during Key Stage 3, particularly linked to digestion. As part of the GCSE, candidates should focus on the practical details and use of their increased knowledge on enzyme action to interpret and explain their results. The additional practical looks at the effect of increasing the concentration of hydrogen peroxide on the enzyme activity of the enzyme catalase.

Link to GCSE Science 2011: 1.32 'Investigate the factors that affect enzyme activity' is a core practical in GCSE Biology 2011 Unit B2 Topic 1.



The effect of pH (core practical)

Questions you could ask to enhance learning and focus your students on important aspects of the practical:

- Why is iodine solution used?
- Why are syringes used to measure the volumes of the solutions?
- Why does the mixture need to be stirred?
- Why are the solutions added in the order stated? (amylase solution, pH solution and starch solution)
- Why is the timer started after the starch solution is added?
- Why must the syringes be used in the same solutions when the investigation is repeated?
- What are the main errors in this procedure?
- How can you improve the procedure?
- What other factors could have affected the results?
- How is the rate of reaction being measured?
- What safety precautions are used in the practical?

Skills that are covered in the practical:

- measuring volumes accurately using syringes
- sampling a reaction at set time intervals, timed by a stop clock
- ability to manipulate apparatus, avoiding cross-contamination and recording observations
- ability to carry out investigation safely

Maths skills:

- mean calculations
- graph drawing



Amylase is an enzyme made in the salivary glands in your mouth and in the pancreas. It catalyses the breakdown of starch into smaller sugar molecules. The iodine test identifies the presence of starch, but does not react with sugar. You will use this test to show how effective amylase is in digesting starch at different pHs.



Your teacher may watch to see if you can:

- work safely
- collect accurate data.

Aim

To investigate the effect of pH on the rate of digestion of starch by amylase.

Prediction

- 1 Predict which at which pH the amylase will digest starch fastest. Explain your prediction.

Method

Apparatus

- | | |
|--------------------------------------|----------------------------|
| • iodine solution in dropping bottle | • pipette |
| • dimple tile | • amylase solution |
| • test tubes | • starch solution |
| • test-tube rack | • solutions of specific pH |
| • syringes | • stop clock |



Safety

Eye protection should be worn.

- A Drop one drop of iodine solution into each depression of the dimple tile.
- B Measure 2 cm³ of amylase solution into a test tube using a syringe.
- C Add 1 cm³ of your pH solution to the test tube using a second syringe. Record the pH of the solution that you are using.
- D Using a third syringe, add 2 cm³ starch solution to the mixture and start the stop clock. Use the pipette to stir the mixture.
- E After 20 seconds, take a small amount of the mixture in the pipette and place one drop of it on the first iodine drop on the tile. Return the rest of the solution in the pipette to the test tube.
- F If the iodine solution turns black, then there is still starch in the mixture and you should repeat step E (after 10 seconds). If it remains yellow, then all the starch is digested and you should record the time taken for this to happen.
- G If there is time, repeat the experiment using a solution with a different pH.

Recording your results

- 2 Collect data from all the groups in the class so that you have results for each of the different pHs. If you have more than one result for each pH, calculate a mean time for each one.
- 3 Draw a table to present these results clearly.

Considering your results

- 4 Plot a line graph to show the time taken for amylase to digest starch with the different pHs.
- 5 Use your graph to describe the effect of pH on the time taken for amylase to digest starch.
- 6 Suggest a reason for the shape of your graph.



Evaluation

- 7** Describe any problems you had with carrying out the experiment.
- 8** Suggest reasons for the problems and how the method could be changed to help reduce the problems.
- 9** Were any of the results surprising? If so, why?
- 10** Do you think you have enough results to support your conclusion? Explain your answer.



Objectives

- B1.9** Explain the effects of temperature, substrate concentration and pH on enzyme activity.
- B1.10** *Investigate the factors that affect enzyme activity.*
- B1.11** Demonstrate an understanding of rate calculations for enzyme activity.

Maths requirements

- 1a** Recognise and use expressions in decimal form.
- 1c** Use ratios, fractions and percentages.
- 2b** Find arithmetical means.
- 2c** Construct and interpret frequency tables and diagrams, bar charts and histograms.
- 4a** Translate information between graphical and numerical form.
- 4e** Draw and use the slope of a tangent to a curve as a measure of rate of change.

Learning outcomes

-  **SB1.9** Describe the effect of temperature on enzyme activity.
-  **SB1.9** Describe the effect of substrate concentration on enzyme activity.
-  **SB1.9** Describe the effect of pH on enzyme activity.
-  **SB1.9** Explain what is meant by the optimum pH/temperature of an enzyme.
-  **SB1.9** Explain why temperature, substrate concentration and pH affect enzyme activity.
-  **SB1.11** Calculate the rate of enzyme activity from experimental data.

Exploring

1. Enzyme activity (pH and/or substrate concentration) – Core practical

Full instructions for an investigation into the effect of pH on enzyme activity are given on Students' sheet CP2 (pH and Enzyme Activity), which is the core practical for this topic. It uses the same reaction (amylase and starch) as for Exploring 1 in *SB1g Enzyme action*. This investigation could be adapted to look at the effect of substrate concentration at a set temperature and pH (e.g. using 2%, 1.6%, 1.2%, 0.8% and 0.4% starch solutions). The reaction between catalase and hydrogen peroxide can be used to investigate the effect of substrate concentration, the instructions for this additional practical are provided on Worksheet SB1h.2.

For investigations into the effect of pH using starch/amylase, the buffer solutions of different pH can be made as follows:



pH	3	4	5	6	7	8
Volume of 0.2 mol dm ⁻³ Na ₂ HPO ₄	20.55	38.55	51.50	63.15	82.35	97.25
Volume of 0.1 mol dm ⁻³ citric acid	79.45	61.45	48.50	36.85	17.65	2.75

Alternatively, addition of dilute hydrochloric acid and sodium hydrogen carbonate solution (prior to adding the amylase) and testing with pH paper/ meter will give a reasonable range of pHs to test. Human amylase works best at a pH of about 7.

Before the lesson, check the speed of the reaction using 2 cm³ of starch with 2 cm³ of amylase and 1 cm³ of buffer at pH 6. It should take about 60 seconds. If the reaction is too fast either reduce the enzyme volume or increase the starch volume. If the reaction is too slow increase the enzyme volume or concentration or reduce the starch volume or concentration.

This practical can be followed using datalogging equipment and a colorimeter or light sensor, though this is not always successful. It is advisable to try this out yourself first.

Safety

Students should wear eye protection while working with iodine solution, and should avoid splashing the solution. Treat splashes on skin or clothing with 0.1 mol dm⁻³ sodium thiosulfate solution until the brown stain is removed, then wash with water. Students should take care when working with water above 50 °C. If using saliva, students should only work with their own saliva. Contaminated apparatus should be rinsed after the activity and placed in bleach or disinfectant solution for about 30 minutes before washing normally.

Support: Restrict the pHs tested by the students to 4, 6 and 8. This should simplify interpretation and produce a peak at pH 6.

Stretch: Ask students to identify the limitations of the method they have used (in particular the limits created by the number of different pHs to be investigated), and consider how best to overcome these given the restrictions of time and equipment available.

Expected results

The optimum pH for human salivary amylase is pH 7. Other amylases may vary from this value, but there should be one pH that clearly allows greater enzyme activity than the others.

The **ALDS** spreadsheet *SB1h pH and enzymes* may be useful to support this activity (see Explaining 1).

The practical on Worksheet SB1h.2 is an optional practical that supports the core practical ideas. For investigating substrate concentration using catalase/hydrogen peroxide: Set up the apparatus as shown in the diagram on Worksheet SB1h.2. Prepare the potato puree in a food blender by peeling the potatoes, chopping the flesh into cubes and blending to a smooth paste. This should be done as close to the lesson as possible, as catalase activity reduces over 2–3 hours. If needed, add a little water to make the paste less viscous. Prepare the range of concentrations of hydrogen peroxide immediately before the lesson. Keep dilutions in clean brown bottles as the peroxide degrades in light. Discard all unused solution, as contaminants in stock bottles can cause explosions after a while. Make sure students use the 100 cm³ measuring cylinder for collecting gas from concentrations above 20 vol.

If bubbles from the rubber tubing are too large, insert a glass pipette or glass tubing into the open end of the rubber tubing.

The table for Question 3 will need to be displayed on the board. Some students may need the diagram on the **ALDS** presentation *SB1h Substrate concentration* to help them understand why the rate of reaction changes with substrate concentration.

Safety

Hydrogen peroxide concentrations of 20 vol and above are IRRITANT. Eye protection and clothes protection should be worn. Rinse splashes of peroxide and potato puree off skin as quickly as possible.

Support: Guide students through calculating the rate of oxygen produced, and the analysis of the collated table, including identification of anomalies and calculation of mean values.



Stretch: Expect students to produce their own diagrams to explain the shape of the curve. They should compare their diagrams with the one on the **ALDS** presentation *SB1h Substrate concentration* to identify any differences.

Expected results

The graph produced from mean values for each concentration should be similar to graph E in *SB1h Enzyme activity* in the Student Book. Rate of reaction should increase in proportion to substrate concentration until all enzyme active sites are filled by substrate molecules. Above this concentration, no further increase in rate of reaction will occur unless more enzyme is added to the mixture.

Course resources

Bio Students' sheet CP2

Equipment

In amylase/starch investigation in the effect of pH, for each pH tested: test tube containing 5 cm³ freshly made 1% starch suspension (mix 5 g soluble starch with a little cold water, pour into 500 cm³ of boiling water and stir well, then boil until you have a clear solution), test tube containing 2 cm³ 1% amylase solution (or 0.5% pancreatin solution) or saliva collected by student (see instructions in SB1e Exploring 1), water bath at optimum temperature for the enzyme (e.g. 37 °C), buffer solution at a set pH (see table above), 5 cm³ syringe or pipette, beaker of water for washing pipette, eye protection, 0.01 mol dm⁻³ iodine solution, well tray (spotting tile).

Optional: if using saliva – hypochlorite (bleach) solution or 1% Virkon solution for disinfection of equipment and benches, small beaker or other container for collecting saliva

In catalase/hydrogen peroxide investigation into substrate concentration: range of concentrations of hydrogen peroxide solution, puréed potato, large syringe, two-holed bung with delivery tube in one hole connected to rubber tubing (see diagram), trough containing water, conical flask, 2 cm³ syringe, 50 cm³ or 100 cm³ measuring cylinder, clamp stand and boss, stop clock or stopwatch, eye protection.



Sample question

This example is taken from the sample assessment material, paper 1BI0/1BH, Q8. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

- 8** Phenolphthalein is an indicator. It is pink in alkaline solutions and turns colourless as the pH decreases.

It can be used to measure the activity of the enzyme lipase on the breakdown of lipids.

Samples of milk containing phenolphthalein were incubated with lipase at different temperatures.

The time taken for the phenolphthalein to turn colourless was recorded and used to calculate the rate of enzyme activity.

Figure 10 shows these results.

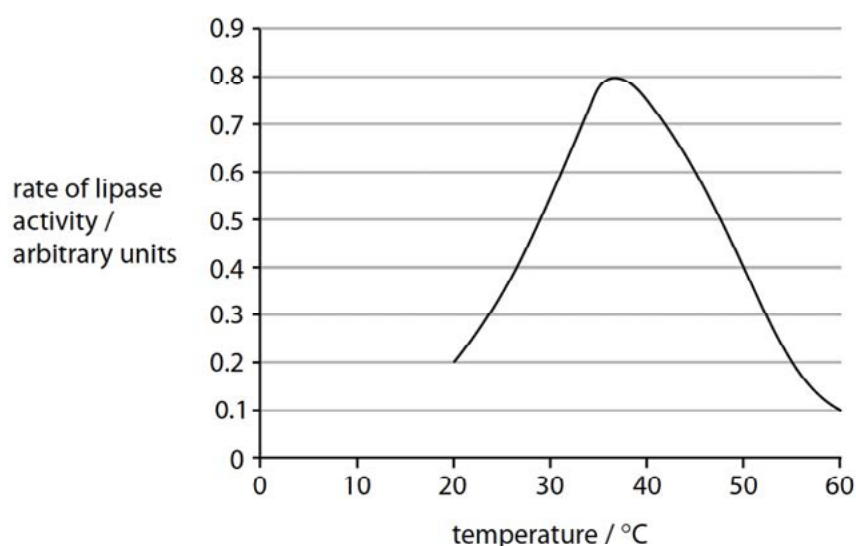


Figure 10

- (a) (i) Explain why phenolphthalein turns colourless when lipase breaks down the lipids in milk.

(2)

Question number	Answer	Mark
8(a)(i)	An explanation that combines identification – application of knowledge (1 mark) and reasoning/justification – application of understanding (1 mark): • fatty acids are formed when the lipids are broken down by lipase (1) • and fatty acids are acidic (so the pH decreases) (1)	(2)



Part (a)(i) is a question where students are asked to apply their knowledge of this core practical to an unfamiliar situation, where it looks at a practical they are not familiar with. They should be able to use their understanding of the core practical they have carried out combined with their theoretical knowledge and the information given in the question to give an answer.

(ii) Describe the effect of temperature on the activity of lipase, as shown in Figure 10.

(2)

Question number	Answer	Mark
8(a)(ii)	An answer that combines up to a maximum of two points to provide a logical description: • as the temperature increases from 20 °C to 37 °C the rate of lipase activity increases (from 0.2 to 0.8) (1) • the rate of lipase activity is optimal at 37 °C (1) • above 37 °C the rate of lipase activity decreases (from 0.8 to 0.1) (1)	(2)

Part (a)(ii) requires students to interpret the data that they have been presented with to describe the effect of temperature on lipase activity. They should be familiar with the general effect of temperature on the activity of enzymes, and this knowledge can be used to interpret the graph.



(iii) Explain why the activity of lipase changes above a temperature of 40 °C.

(2)

Question number	Answer	Mark
8(a)(iii)	An explanation that combines identification – application of knowledge (1 mark) and reasoning/justification – application of understanding (1 mark): • an increase in temperature above 40 °C causes changes in the shape of the active site of the enzyme (1) • therefore the enzyme becomes denatured and no longer functions (1)	(2)

This part extends the candidates' knowledge to explain the effect of high temperature on the activity of lipase. This is an application mark as it applies their knowledge of the mechanisms of enzymes to practical results that are presented in the question.

(b) A student investigated the time taken for amylase to breakdown a 10% starch solution into glucose at 37 °C. The student repeated the investigation five times.

Figure 11 shows the results.

time taken for amylase to produce glucose (s)				
test 1	test 2	test 3	test 4	test 5
120	125	110	115	118

Figure 11

(i) Calculate the rate of amylase enzyme activity for the 10% starch solution.

(3)

rate = s⁻¹



Question number	Answer	Additional guidance	Mark
8(b)(i)	- mean= $588/5 = 117.6$ (1) - rate = $1 \div 117.6$ (1) 0.0085 (1)	award full marks for correct numerical answer without working accept $1000/t$ accept $10/t$	(3)

This part asks candidates to calculate the rate of enzyme activity by first calculating the mean, and then working out the rate. Candidates have to obtain the correct data from the table and use it to calculate the rate. It focuses on the maths skills required.



Core practical 3: Food tests

1.13B Core practical: Investigate the use of chemical reagents to identify starch, reducing sugars, proteins and fats

Links to the specification content

- 1.12 Explain the importance of enzymes as biological catalysts in the synthesis of carbohydrates, proteins and lipids and their breakdown into sugars, amino acids and fatty acids and glycerol
- 1.14B Explain how the energy contained in food can be measured using calorimetry

Introducing the practical

This core practical is only required for biology and not combined science. It covers techniques and skills that students are likely to have encountered during Key Stage 3. Consequently, the resource to support this core practical suggests that students plan the investigation to test a range of foods for starch, reducing sugars, proteins and fats. This provides students with the opportunity to develop their skills in writing methods, determining what equipment is required and considering safety hazards and how they would deal with these. It may be necessary to split this practical into two lessons, one to plan and one to complete the investigation.

Students will be required to remember the reagents needed to test for starch, reducing sugars, protein and lipids, the methods used for the food tests as well as both positive and negative observed results. They will then be able to link this information to the role of enzymes in the synthesis of carbohydrates, proteins and lipids and their breakdown into sugars, amino acids and fatty acids and glycerol. This core practical is in topic 1 and as such could be linked to relevant theoretical knowledge across both paper 1 and paper 2.

Link to GCSE Science 2011: 3.14 'Explain the role of digestive enzymes, including:

- a carbohydrases, including amylase, which digest starch to simple sugars
- b proteases, including pepsin, which digest proteins to amino acids
- c lipase, which digests fats to fatty acids and glycerol'

in GCSE Biology 2011 Unit B2 Topic 3.



Questions you could ask to enhance learning and focus your students on important aspects of the practical:

- Why should all the food tests be done on each food sample?
- What effect could cross contamination have on the observed results?
- How can cross contamination of samples be avoided?
- What safety hazards will be encountered during the practical work?
- How can safety hazards be minimised or prevented?
- What is the best way to present results that are qualitative?
- How could qualitative food tests be modified to produce semi-quantitative or quantitative data?
- Why might the result for reducing sugars be negative in a food whose food label shows it contains sugar?
- What are the roles of each food group in the body?
- How do the results for each food test link to its potential role as part of a balanced diet?

Skills that are covered in the practical:

- Determining equipment needed for a practical
- Writing a method
- Recognising safety hazards and controlling risks
- Careful labelling and manipulation of apparatus to avoid cross contamination
- Recording of quantitative data in a results table
- Use of scientific ideas to interpret results

**Your teacher may watch to see if you can...**

- follow instructions carefully
- work safely, reducing the risk of harm from hazards.

You will be given a range of powdered foods. Use the tests below to identify whether each food contains the substances that the reagents test for. Use your results to help you identify the foods from the list you are given. Remember to wipe the spatula and stirrer clean between tests with a paper towel, to prevent cross-contamination.

Aim

To identify starch, reducing sugars, proteins and lipids in foods.

Method**Apparatus**

- eye protection
- water
- measuring cylinder
- spatula
- powdered foods
- paper towels
- test tubes, racks and bungs
- stirrer
- iodine solution in dropper bottle
- Benedict's solution
- potassium hydroxide solution
- copper sulfate solution
- ethanol
- cold water
- water bath at 70 °C

**Safety**

Wear eye protection.
Wash any splashes from skin quickly.
Do not taste any of the food substances.
Potassium hydroxide can be harmful to skin and eyes.
Avoid scalding with hot water.

Iodine test for starch

- A** Place one spatula of powdered food on a dish.
- B** Using a dropper, place a few drops of iodine solution onto the food.
- C** Record the letter of the food and any change in the colour of the solution.

Benedict's test for reducing sugars

- D** Place two spatulas of powdered food into a test tube. Add about 1 cm³ depth of water to the tube and stir to mix.
- E** Add an equal volume of Benedict's solution and mix.
- F** Place the tube in a water bath at about 95 °C for a few minutes.
- G** Record the letter of the food and the colour of the solution.

Biuret test for protein

- H** Place two spatulas of powdered food into a test tube. Add about 1 cm³ depth of water to the tube and stir to mix.
- I** Add an equal volume of potassium hydroxide solution to the tube and stir.
- J** Add two drops of copper sulfate solution and stir.
- K** Record the letter of the food and the colour of the solution after a few minutes.

Emulsion test for lipids

- L** Place two spatulas of powdered food into a test tube.
- M** Add 2 cm³ of ethanol to the tube. Place a bung firmly in the end of the tube and shake the tube vigorously.
- N** Allow the contents to settle.
- O** Pour the liquid from the top of the mixture into a test tube half-filled with water.
- P** Record the letter of the food and whether the water is cloudy or clear.



Name _____ Class _____ Date _____

Recording your results

- 1 Record your results in the table. Add more rows if needed.

Food	Colour at end of ...			
	iodine test	Benedict's test	biuret test	emulsion test
A				
B				
C				
D				

Considering your results/conclusions

- 2 Which foods contained:

- a starch _____
- b reducing sugar _____
- c protein _____
- d lipid? _____

- 3 Do any of your tests give an indication of how much of a substance a food contains? Give a reason for your answer.

Evaluation

- 4 Identify any problems you had with this experiment, and explain how the method could be improved to reduce or avoid these errors.



Objectives

- B1.13B** Investigate the use of chemical reagents to identify starch, reducing sugars, proteins and fats.
- B1.14B** Explain how the energy contained in food can be measured using calorimetry.

Maths requirements

- 1a** Recognise and use expressions in decimal form.
- 2c** Construct and interpret frequency tables and diagrams, bar charts and histograms.
- 3c** Substitute numerical values into algebraic equations using appropriate units for physical quantities.

Learning outcomes

-  **SB1.13B** Describe how to test for starch in food.
-  **SB1.13B** Describe how to test for reducing sugars in food.
-  **SB1.13B** Describe how to test for proteins in food.
-  **SB1.13B** Describe how to test for lipids in food.
-  **SB1.14B** Explain how calorimetry can be used to measure the energy in food.
-  **SB1.14B** Evaluate calorimetry tests for accuracy.

Exploring

1. Identifying substances in foods

This practical forms part of the core practical requirement of the specification. It is supported by the information on Students' sheet CP3 (Testing food). There are several different tests that students can use for testing some of the substances in foods. These, with preferred methods given first, include:

- starch: solution of iodine in potassium iodide (qualitative)
- lipid: ethanol/emulsion (qualitative), smear test (qualitative), Sudan III (qualitative)
- reducing sugars: Benedict's test (semi-quantitative), Clinistix[®] (glucose, semi-quantitative)
- protein: biuret test (semi-quantitative), Albustix[®] (semi-quantitative, only for some proteins).

Any semi-quantitative test can also be used qualitatively. Worksheet SB1f.1 guides students in using the iodine test, emulsion test, Benedict's test and biuret test. These could be replaced with others if they are more appropriate to your students.

The practical work is most simply carried out on powdered foods, such as powdered potato, full and/or low fat powdered milk, whey (protein) powder, powdered egg white (use commercially available albumen) and powdered glucose. You could also include icing sugar if you want to show that sucrose is non-reducing. Label each powder as 'food A', 'food B' etc. and ask students to identify which is which from a list of names, using their results.

An alternative to a water bath for the Benedict's test is a large beaker of water heated to boiling, before turning off the heat source. Tubes should be placed in the water while it is still very hot.

Biuret solution does not keep, so only prepare as much as is needed.

**⚠ Safety**

Remind students that they should not taste any of the foods. Care should be taken with very hot water, to avoid scalding.

Support: Name each powder with its correct food name, and ask students to predict how each will respond to the tests before carrying them out. They should record their predictions in a table for comparison with the actual results.

Stretch: If using icing sugar, after students have produced a negative test for reducing sugar, you could show them how to hydrolyse the sugar by adding dilute hydrochloric acid (about half as much as the volume of tube contents) and placing the tube in a boiling water bath for about 10 minutes. After the tube has cooled, add some dilute sodium hydrogencarbonate solution until the fizzing stops, then repeat the Benedict's test on the mixture.

Challenge students to adapt one of the tests to make it more quantitative. If needed, suggest the idea of testing solutions of known concentration of a substance. (This is covered further in Explaining 2.)

Expected results

The results of the tests will depend on the foods used. The table below shows results from the suggested foods. Note that using coloured foods may make some colour changes more difficult to see.

Food	Iodine test	Benedict's test	Biuret test	Emulsion test
full-fat milk	yellow–orange	yellow	purple	cloudy
whey	yellow–orange	bright blue	purple	clear
egg white	yellow–orange	bright blue	purple	clear
potato	black–blue	bright blue	light blue	clear
glucose	yellow–orange	red precipitate	light blue	clear
(icing sugar)	yellow–orange	bright blue	light blue	clear

Errors are most likely to occur if equipment is not cleaned properly between tests and it becomes contaminated with another sample.

Course resources :

Bio Students' sheet CP3

Equipment (per student or group)

eye protection, food samples – powdered potato, full and/or low-fat powdered milk, whey (protein) powder, powdered egg white (use commercially available albumen), powdered glucose – water, measuring cylinder, spatula, paper towels, test tubes, racks and bungs, stirrer, iodine solution (1 g iodine in 100 cm³ 0.5 mol dm⁻³ potassium iodide solution) in dropper bottle, Benedict's solution (prepared according to CLEAPSS Recipe sheet 11 (qualitative) or 12 (for quantitative measurements)), 5% potassium hydroxide and 1% copper sulfate solution or biuret solution (prepared according to CLEAPSS Recipe sheet 15) in dropper bottle, absolute ethanol, water bath at 95–100 °C

Optional: icing sugar, dilute hydrochloric acid (approximately 0.1 mol dm⁻³), dilute sodium hydroxide solution (approximately 0.1 mol dm⁻³), water bath at 100 °C, Sudan III stain (dissolve 0.5 g dye in 70 cm³ ethanol (highly flammable) and 30 cm³ water, using a warm water bath and filter) in dropper bottle



Sample question

These examples are taken from the sample assessment material. The question is from 1BI0/1F. The first part of the question requires knowledge gained from the core practical. The second part of the question shows how skills gained from completing core practicals could be applied to new contexts in exam questions. The question links to sugar, the test for which is described in the first part of the question. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

3 The sugar molecule glucose can be detected by a chemical test.

(a) Use words from the box to complete the sentences.

(2)

blue-black	iodine	brick red
Biuret	lilac	Benedict's

The reagent is added to a tube containing a solution of glucose.

The tube is heated and the colour changes to a colour.

Question number	Answer	Mark
3(a)	- Benedict's (1) - brick red (1) Answers must be in the correct order	(2)

This question requires recall of the reagent used to test for the presence of glucose and the colour change observed with a positive result.

Sugary drinks have been linked to tooth decay.

Tooth decay occurs when the enamel on teeth is dissolved.

A scientist investigates the effect of five different drinks on artificial tooth enamel.

She places 10 g of artificial tooth enamel into 100 ml of each drink. These are left for seven days.

The percentage change of mass for each sample of enamel is calculated.

Figure 5 shows the results.

drink	cola	milk	lemonade	squash	milkshake
percentage change of mass (%)	-3.4	0.0	-2.8	-0.6	-1.6

Figure 5



(b) (i) Which drink is most likely to cause tooth decay?

(1)

- ☒ **A** cola
- ☐ **B** lemonade
- ☒ **C** milkshake
- ☐ **D** squash

Question number	Answer	Mark
3(b)(i)	A	(1)

This question requires the interpretation of a set of results from an investigation that will be unfamiliar to students. The information in the stem of the question is needed to interpret the results given in the table. This would also require students to have an understanding of the maths concept of percentage change in mass.

(ii) Explain why it might be better to drink milk rather than a milkshake.

Use data from Figure 5.

(2)



Question number	Answer	Mark
3(b)(ii)	An explanation that combines identification via a judgement (1 mark) to reach a conclusion via justification/reasoning (1 mark): • milk does not change the mass of the enamel/milkshake reduces the mass of the enamel (1) • so therefore milk causes less tooth decay (1)	(2)

This question requires students to justify a conclusion by comparing two pieces of data and combine it with information given in the stem of the question as part of the justification.

The scientist is concerned that the conclusions from this experiment might **not** show the real effect of sugary drinks on teeth.

(iii) Give **two** ways in which the scientist could improve the investigation.

(2)

1

2

Question number	Answer	Mark
3(b)(iii)	Any two of the following points: • use real teeth (1) • clean the teeth (1) • expose the teeth for shorter time periods repeatedly (1)	(2)

This question requires students to recognise the limitations of an unfamiliar investigation and suggest possible improvements. Students should work on developing this skill when completing practicals during the course.



Core practical 4: Osmosis in potato strips

1.16 Core practical: Investigate osmosis in potatoes

Links to the specification content

- | | |
|------|--|
| 1.15 | Explain how substances are transported into and out of cells, including by diffusion, osmosis and active transport |
| 1.17 | Calculate percentage gain and loss of mass in osmosis |

Introducing the practical

This core practical uses potato strips to demonstrate osmosis. The potato strip will lose or gain mass, due to osmosis, depending on the concentration of solutes in the solution. The practical can be completed within an hour lesson and combining class data allows the opportunity for enhanced analysis of the results. The practical pre-prepares the sucrose solutions and potato strips but it would be helpful to discuss how this was done to control relevant variables. The practical addresses a few areas which candidates find difficult including the idea that a solution with a high concentration of solute molecules contains fewer water molecules and the calculation of percentage change in mass. Graphical analysis of the results gives the opportunity for candidates to determine the isotonic concentration of the potato.

Link to GCSE Science 2011: 2.21 'Investigate osmosis' is a core practical in GCSE Biology 2011 Unit B2 Topic 2.



Osmosis in potato strips

Questions you could ask to enhance learning and focus your students on important aspects of the practical

- What variables can arise with the potato strips?
- Why do the potato strips have to be blotted dry?
- Why are the potato strips the same width and length?
- What precautions must be taken to ensure the mass of the potato is accurately recorded?
- How have the sucrose solutions been prepared?
- Which sucrose solution has the highest number of water/solute molecules?
- Why should the potato strips be left in the solutions for at least 15 minutes?
- What are the main errors in this procedure?
- How can you improve the procedure?
- What safety precautions are used in the practical?
- What is the benefit of combining the class data before the analysis is completed?

Skills that are covered in the practical:

- Using a balance accurately
- Accurate labelling to identify samples in an investigation
- Recording observations (e.g. mass of potato strips)
- Ability to carry out investigation safely

Maths skills:

- Calculating percentage change in mass
- Identifying anomalous results
- Calculating mean values
- Plotting a scatter graph
- Determining the graph intercept point to identify the isotonic value

**Your teacher may watch to see if you can:**

- measure accurately
- work carefully.

Osmosis is the overall movement of water molecules from a region where there are more of them in a particular volume to a region where there are fewer, through a **semi-permeable** membrane. The cells in a potato contain many substances dissolved in water. The cells are surrounded by cell membranes that are permeable to water. When a strip of potato is placed in a solution, the overall movement of water molecules between the potato cells and the solution will depend on which has the higher **concentration** of solutes. In this practical you will investigate osmosis in potato strips in terms of the percentage change in mass of potato in different solutions.

Aim

To investigate how solution concentration affects percentage change in mass of potato strips due to osmosis.

Prediction

- 1 For each of the solutions you will use, predict whether the potato strips will gain mass, lose mass or keep the same mass. Explain your predictions.

Method

Apparatus

- 4 potato strips
- accurate balance
- 4 boiling tubes and rack (or beakers)
- waterproof pen
- 4 sucrose solutions: 0%, 40%, 80%, 100%
- forceps
- paper towels

Safety

Do not drink any of the solutions or eat the potatoes.

- A Using the waterproof pen, label each tube with the name of one of the solutions. Place the boiling tubes in the rack.
- B Dry a potato strip carefully by blotting it with a paper towel. Measure its mass on the balance.
- C Place the potato strip into one of the tubes. Record the label on the tube and the mass of the strip in your results table (see next page).
- D Repeat steps B and C until all strips have been measured and placed in tubes.
- E Carefully fill each tube with the appropriate solution, so that the potato is fully covered. Leave the tubes for at least 15 minutes.
- F For each potato strip, use the forceps to remove it from its tube, blot dry on a paper towel and measure its mass again. Record all the masses in the results table.



Recording your results

- 2 Draw up a table with the following headings. Complete the first three columns with the solution descriptions and your measurements from the experiment.

Solution	A Mass of potato strip at start (g)	B Mass of potato strip at end (g)	C Change in mass (g) = B – A	% change in mass $= \frac{C}{A} \times 100\%$

- 3 Complete column **C** by calculating the change in mass for each potato strip using the formula shown.
- 4 Complete column 5 by calculating the percentage change in mass for each potato strip using the formula shown.
- 5 Compare the results for percentage change in mass from all groups in the class for each solution. Identify any results that seem very different from the others (outliers). Try to find a reason why they are so different.
- 6 Using all results except outliers, calculate a mean value for percentage change in mass for each solution.
- 7 Draw a suitable chart or graph to show the mean percentage change in the mass of each potato strip on the y-axis against the solution description on the x-axis.

Considering your results/conclusions

- 8 Describe the pattern shown in your chart or graph.
- 9 Explain the pattern shown in your chart or graph, using the word 'osmosis' in your answer.
- 10 Explain why you calculated percentage change in mass.
- 11 Explain why calculating a mean value from several repeats of the same experiment is more likely to give a value that can be reproduced by others.

Evaluation

- 12 Describe any problems that you had with the experiment. Suggest how these could be reduced or avoided to produce better results.



Objectives

- B1.15** Explain how substances are transported by diffusion, osmosis and active transport.
- B1.16** *Investigate osmosis in potatoes.*
- B1.17** Calculate percentage gain and loss of mass in osmosis.

Maths requirements

- 1c** Use percentages.
- 2b** Find arithmetic means.
- 4a** Translate information between graphical and numeric forms.

Learning outcomes

-  **SB1.15** State that substances are transported by diffusion, osmosis and active transport.
-  **SB1.15** Describe how substances are transported by active transport (including the need for energy).
-  **SB1.15** Explain how substances are transported by diffusion.
-  **SB1.15** Explain how substances are transported by osmosis.
-  **SB1.15** Explain the effects of osmosis on cells and tissues.
-  **SB1.16** Investigate osmosis in potatoes.
-  **SB1.17** Calculate percentage gain and loss of mass in osmosis.



Exploring

1. Diffusion and osmosis – Core practical

Students' sheet CP4(Osmosis in potatoes) provides support for the core practical on osmosis in potato slices (specification statement B1.16), and Worksheet SB1i.2 supports the optional suggested practical on diffusion using agar. Both practicals include calculations that some students may have problems with. In the osmosis practical, results from different groups are collated and compared to check for outliers, then mean values calculated for each solution. It may help to prepare a class spreadsheet for displaying all the results for discussion. The identification of outliers may provide useful information for the evaluation of the investigation. If students need further practice in calculating means, this can be added to the diffusion practical by comparing groups' results in a similar way.

Osmosis: The osmosis practical measures the percentage change in mass of strips of potato placed in different concentrations of solution. Using a coloured sugar syrup, such as blackcurrant squash (not sugar-free), makes it easier for students to see that the solutions are of different concentrations. However, a concentrated sucrose solution with added food colouring, which is then used to produce different dilutions, is also suitable.

Note that some students may be confused by the idea that a more concentrated solution contains proportionately fewer water molecules than a weaker or more dilute solution. So it may be worth checking understanding of this when students are carrying out this practical. If needed, talk in terms of a higher concentration of solute containing fewer water molecules.

The following table starts with a sucrose or blackcurrant squash concentration of about 550 g/dm³ of sucrose.

Concentration of initial solution (%)	Volume of blackcurrant squash needed to make 30 cm ³ of solution	Volume of water needed to make 30 cm ³ of solution	Final volume of solution made (cm ³)
0 (pure water)	0	30	30
40	12	18	30
80	24	6	30
100	30	0	30

Cut the potato strips as near to lesson time as possible using a cork borer or potato chipper to get identical diameters/widths. Then cut them all to the same length. Make sure this length will fit inside a boiling tube if that is what students will be using. Wrap the strips in a damp cloth or plastic film until the lesson. This means that the strips placed in pure water should gain mass during the experiment, as the cells will not be fully turgid at the start.

The **ALDS** spreadsheet *SB1i Percentage change in osmosis* contains data that could be used with students if they have not been able to collect their own results. The spreadsheet then guides students through plotting the data and analysing it.

Support: Students may need help in drawing up their table and completing the calculations. They may also need help working out how to record negative numbers on their chart.

Stretch: Ask students how they could adapt this practical to find the concentration inside potato cells.

Safety

Students should be warned not to taste or drink any of the solutions, or taste the potato.



Expected results

Students should find that the potato strip in pure water gains mass, while the rest lose mass in relation to how much water was in the solution (i.e. the potato in the solution with least water (100% solution) loses most mass).

Diffusion (optional): For the agar cube practical, the agar will need preparing ahead of the lesson to give it time to set. Use 2 g plain agar powder in 100 cm³ water, with added 0.01 mol/dm³ sodium hydroxide and either universal indicator or phenolphthalein, enough to colour the agar to indicate alkalinity. Place the container in a water bath of boiling water until the solution boils. Agar cubes of side length 2 cm, 1 cm and 0.5 cm can either be cut before the lesson or students could be given a larger block from which to cut their own cubes. In the latter case, tell students the dimensions to cut. Explain to students that the agar contains indicator that will change colour in the presence of the acid, and that this change will be used to measure how far the acid has diffused into each cube.

Support: Work with students to complete the calculations of volume and rate of diffusion.

Stretch: Ask students to consider how good a model they think agar cubes are for investigating diffusion into cells, using similarities and differences between agar and cells to help them answer the question.

Safety

Wear eye protection and rinse splashes from skin when preparing the agar cubes and hydrochloric acid, as well as during the practical.

Expected results

Students should find that most, if not all, of the smallest cube will have changed colour due to the diffusion of the acid through the block. In the other cubes, it is unlikely that the acid will have diffused to the centre. This suggests there is a physical limit to cell size, as beyond a certain size substances take too long to diffuse in and out from the centre of a cell to support life processes effectively.

Course resources

Bio Students' sheet CP4

Equipment (per group)

Osmosis: four potato strips of identical size, accurate balance, four boiling tubes and rack (or beakers), waterproof pen, four labelled solutions containing different concentrations of initial (approx. 550 g/dm³) sucrose solution (0%, 40%, 80%, 100%), forceps, paper towels

Diffusion: agar cubes containing sodium hydroxide and universal indicator or phenolphthalein (one cube each of side lengths 2 cm, 1 cm and 0.5 cm or an agar block large enough for students to cut their own cubes), 20 cm³ 0.1 mol/dm³ hydrochloric acid, 100 cm³ beaker, forceps, paper towel, rinsing water, white tile, knife, stopclock or watch, eye protection



Sample question

This example is taken from the sample assessment material, paper 1BI0/1BH, Q5(a). The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams.

- 5 Diffusion, active transport and osmosis can be used to move substances into and out of cells.

(a) A student was investigating osmosis in potato cubes.

He used the following method:

cut a potato into equal-sized cubes

- record the mass of each potato cube
- place each potato cube into different concentrations of salt solution
- remove the potato cubes after 30 minutes
- dry the potato cubes and record the final mass of each cube.

He plots his results on a graph shown in Figure 6.

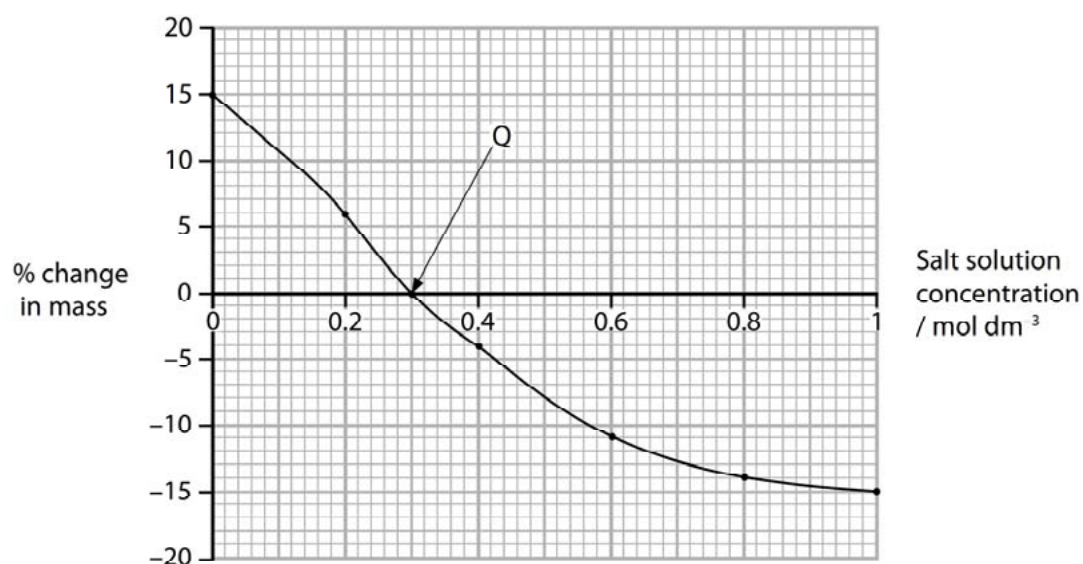


Figure 6

The method controls a number of variables.



- (i) Name **one** other variable that needs to be controlled during the student's investigation.

(1)

Question number	Answer	Mark
5(a)(i)	Any one variable from • temperature • amount of drying • type of potato • age of potato	(1)

This question requires candidates to understand the controlled variables in the core practical. The direct link to the core practical makes this a knowledge-based question.

- (iii) Explain the conclusion that can be made about point Q on Figure 6.

(2)

Question number	Answer	Mark
5(a)(iii)	An explanation that combines identification via a judgement (1 mark) to reach a conclusion via justification/reasoning (1 mark): any one identification point from: • there is no change in mass at 0.3 mol dm^{-3} (check once drawn) (1) • this is the isotonic salt concentration in the potato (1) Plus reasoning/justification • because there is no net movement of water/no salt concentration gradient (1)	(2)

This is an analysis question as it requires candidates to draw a conclusion about the specific data point on the graph. They will need to explain that the value represents the point where there is zero percentage change in mass.



- (iv) Give one way that the student could obtain more data to increase the accuracy of point Q.

(1)

Question number	Answer	Mark
5(a)(iv)	repeat the test using intermediate concentrations (between 0.2 and 0.4 mol dm³)	(1)

This is also an analysis question requiring candidates to suggest how the investigation could be extended to collect more data to accurately determine the point where there is zero percentage change in mass.



Core practical 5: Microbial cultures

5.18B Core practical: Investigate the effects of antiseptics, antibiotics or plant extracts on microbial cultures

Links to the specification content

- 5.10B Describe how plants defend themselves against attack from pests and pathogens by producing chemicals, some of which can be used to treat human diseases or relieve symptoms
- 5.16 Explain that antibiotics can only be used to treat bacterial infections because they inhibit cell processes in the bacterium but not the host organism
- 5.17B Explain the aseptic techniques used in culturing microorganisms in the laboratory, including the use of an autoclave to prepare sterile growth medium and petri dishes, the use of sterile inoculating loops to transfer microorganisms and the need to keep petri dishes and culture vials covered
- 5.19B Calculate cross-sectional areas of bacterial cultures and clear agar jelly using πr^2

This core practical provides students with the opportunities to develop their skills handling microorganisms including aseptic techniques. The practical spreads bacteria onto agar in petri dishes. Filter paper discs inoculated with antiseptics, antibiotics or plant extracts are then placed onto the agar before the plate is incubated. As the bacteria grow, the antiseptics, antibiotics or plant extracts kill the bacteria producing a zone of inhibition. The larger the zone of inhibition the more effective the chemical.

The results of the investigation can be analysed and the area of the clear agar jelly surrounding the filter paper discs can be calculated using πr^2 . Students should consider ways in which the results of the investigation can be presented and how this type of investigation could be used in a clinical or industrial setting. Students should also be able to explain why the specific aseptic precautions are used.

Link to GCSE Science 2011: 3.15 'Investigate the effects of antiseptics or antibiotics on microbial cultures' is a core practical in GCSE Biology 2011 Unit B1 Topic 3. Also, 1.27 'Demonstrate an understanding of Louis Pasteur's contribution to the development of aseptic techniques' in GCSE Biology 2011 Unit B3 Topic 1.



Questions you could ask to enhance learning and focus your students on important aspects of the practical:

- Why are aseptic precautions necessary when handling bacteria and other microorganisms?
- Why are bacteria used in this investigation?
- What types of bacteria should be used for this type of investigation?
- Why should a temperature of 30°C be used to culture microorganisms in a school laboratory?
- Why should the plates and cultures only be opened close to a Bunsen flame?
- What are the different variables that need to be controlled during this investigation?
- Why are the chemicals added to the plate on a filter disc?
- What does the agar used for culturing the bacteria contain?
- What is the difference between antiseptics, antibiotics and plant extracts?
- How could investigations similar to this core practical be used in a clinical environment?
- How could investigations similar to this core practical be used in the search for new antibiotics or antiseptics?
- Why do antibiotics only target bacterial cells?

Skills that are covered in the practical:

- Identification of risks associated with handling microorganisms
- Use of different aseptic procedures
- Safe handling of apparatus
- Interpretation and presentation of results
- Identification of anomalous results
- The importance of controls in investigations

Maths skills:

- Measurement of radius
- Calculating the area of a circle
- Calculating mean values from repeats
- Presenting data in a bar graph



Your teacher may watch to see if you can:

- work safely and aseptically with microorganisms.

Aim

To investigate the effect of antibiotics on bacteria.

Method

Apparatus

- Petri dish with lid
- screw-top bottle of sterile liquid nutrient agar (keep in water bath until needed) sterilised in an autoclave
- bacterial culture in screw-top bottle
- sterile pipette in wrapper
- sterile spreader in wrapper
- beaker of disinfectant
- two small filter paper discs of different antibiotic concentration or type
- small disc of sterile filter paper
- sticky tape
- marker pen
- forceps
- ethanol (IDA)
- ruler
- Bunsen burner and heat-resistant mat

Safety

Plates must be taped closed as in the diagram. This allows air in and does not encourage the growth of pathogenic bacteria.

Dispose of all cultures and equipment safely, as instructed by your teacher.

Take care to avoid burning fingers when flaming the neck of an agar bottle.

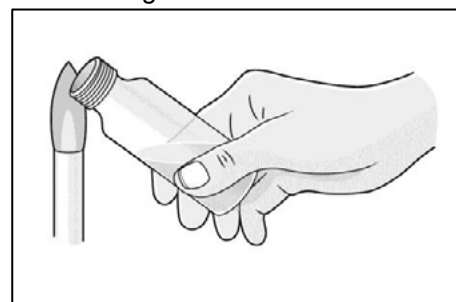
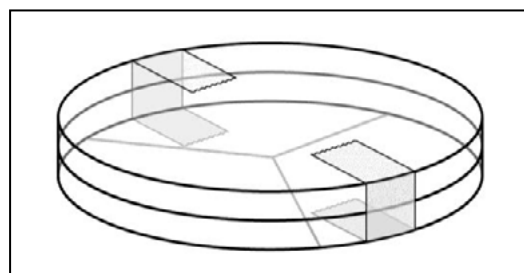
Avoid touching eyes or skin after handling bacterial cultures. Wash splashes immediately with water.

Wash hands thoroughly before the practical and again before leaving the laboratory.

Ethanol (IDA) is hazardous and highly flammable. Keep away from open flames, except as described in the method.

Pouring an agar plate

- Keeping the lid on the Petri dish, turn the dish upside down. Use the pen to draw three sections on the base, as shown in the diagram. Label one section 'control' and the other two sections with the name or concentration of each antibiotic. Add your initials and the date near the edge of the dish. Turn the dish the right way up.
- Light the Bunsen burner and set it to a roaring flame.
- Work in a pair to pour the plate. One student should unscrew the cap of the nutrient agar bottle and quickly pass the glass neck of the bottle through the Bunsen flame, as shown in the diagram. The other student should lift the lid of the Petri dish just enough for the agar to be poured carefully into the dish. Pour in enough agar to half fill the depth of the Petri dish base. Replace the dish lid immediately. Flame the open neck of the agar bottle again before screwing the cap back on.
- Leave the agar to solidify.



Making a bacterial plate

- Remove the pipette from its wrapper and do not put it down.
- Unscrew the cap of the bottle of bacterial culture and quickly pass the neck of the bottle through the Bunsen flame.
- Draw a small amount of culture into the pipette then flame the neck of the bottle again and replace the lid.



- H** Lifting the lid of the Petri dish as little as possible, gently add two drops of culture to the agar. Replace the dish lid and place the pipette in disinfectant.
- I** Unwrap the spreader and, lifting the dish lid as little as possible, gently spread the culture drops across the agar using a back-and-forwards motion with the spreader.
- J** Replace the dish lid and place the spreader in disinfectant.

Adding antibiotic discs

- K** Sterilise the forceps by dipping them into ethanol then passing them through the Bunsen flame to ignite the ethanol.
- L** Use the forceps to pick up the sterile filter paper disc. Lift the dish lid just enough so that the forceps do not touch the bacterial layer on the agar in the dish, and carefully place the disc on the section labelled 'control'. Replace the dish lid as quickly as possible.
- M** Sterilise the forceps as before (step **K**). Then repeat step **L** with one of the antibiotic discs, placing it on the appropriate section of agar. Remember to replace the dish lid as quickly as possible.
- N** Repeat step **M** with the other antibiotic disc.
- O** Tape the lid onto your Petri dish with two pieces of tape, as shown in the top diagram on the previous last page, and invert the dish. Leave it at 20–25 °C for two to three days.
- P** Look carefully at your dish. **Do not open it.**

Recording your results

- 1** Measure the diameter of the circle around each disc where there is no bacterial growth.
- 2** Divide each diameter by 2 to calculate the radius (r) for each circle, and then calculate the area of no bacterial growth using the formula $\text{area} = \pi r^2$
- 3** Draw up and complete a table to record the area of no bacterial growth for each disc.

Considering your results/conclusions

- 4** Explain what your results show about the effect of antibiotics on bacteria.
- 5** Compare your results with those of other groups.
 - a** Did other groups get the same results? If not, suggest why not.
 - b** Explain which of the discs was the most effective at killing bacteria.

Evaluation

- 6** Suggest a way in which the method could be improved, and give a reason for your suggestion.
- 7**
 - a** Identify steps in the method that contributed to working aseptically.
 - b** Explain the importance of working aseptically in this practical.



Objectives

- B5.16** Explain that antibiotics can only be used to treat bacterial infections because they inhibit cell processes in the bacterium but not the host organism.
- B5.18B** *Core Practical: Investigate the effects of antiseptics, antibiotics or plant extracts on microbial cultures.*
- B5.20** Describe that the process of developing new medicines, including antibiotics, has many stages including discovery, development, preclinical and clinical testing.

Maths requirements

- 1a** Recognise and use expressions in decimal form.
- 5c** Calculate areas of triangles and rectangles, surface areas and volumes of cubes.

Learning outcomes

-  **SB5.16** Define the term antibiotic (as medicines that inhibit cell processes in bacteria).
-  **SB5.16** Explain why antibiotics are useful for treating bacterial infections (because they do not damage human cell processes).
-  **SB5.16** Explain why antibiotics cannot be used to treat infections by pathogens other than bacteria.
-  **SB5.20** Describe the stages of development of new medicines.
-  **SB5.20** Explain why each stage of the development of a new medicine is needed.



Exploring

1. Core practical – Investigating the effect of antibiotics

This practical forms part of the core practical requirement of the specification. It is supported by the information on *Students' sheet CP5 (Investigating the effect of antibiotics)*.

Full instructions are given on Students' sheet CP3. Discs of different concentration of the same antibiotic could be used. Alternatively, different antibiotics could be compared. The method can be adjusted to look at the effect of different antiseptics or plant extracts if preferred. (Note that the effect of plant extracts is covered in detail by the practical work in Exploring 1 of *SB5g Plant defences*.)

The method allows students to pour their own agar plates then inoculate them with bacteria, to develop their skills in aseptic technique. However, nutrient agar plates could be prepared for students just before the lesson. Seal plates in plastic bags if they are not used straight away, to stop the agar drying out. Show students the preparation of agar in the autoclave to sterilise it. If students will not be preparing their own agar plates, demonstrate the process and discuss the various parts of the process that contribute to aseptic technique.

If students pour their own plates, after the sterile agar has been melted in bottles in boiling water, allow it to cool for 5–10 minutes before placing the bottles in a water bath at 50 °C to keep the agar molten until students need it. Warn students that the bottles are warm.

Some parts of the method are very fiddly and may benefit from a little practice beforehand. Alternatively, students could work in pairs to pour and inoculate plates. Make sure, though, that they understand the need for aseptic techniques and work as effectively as possible.

Students should work on a surface that has been disinfected for at least 10 minutes with 1% VirKon and the surface should be re-disinfected after the activity. The disinfected surface can be most easily achieved by placing an impervious surface (e.g. ceramic tile, piece of plastic, or laminated sheet of A4 paper) into 1% VirKon in a bowl so that its surface is completely covered. The surface should be left in place for at least 10 minutes before use and then blotted dry using a paper towel. The impervious surface should be returned to the disinfectant after the practical.

After the first lesson, the plates should be incubated upside down at 20–25 °C for two to three days. If the second lesson is later than this, further growth can be slowed by refrigerating the plates. Take plates out of the fridge at least 30 minutes before the lesson, to allow them to come to room temperature and for any condensation to evaporate.

Before students record their results, discuss which method to use. Measurement of the diameter of the clear area can be done using a ruler or by measuring against millimetre graph paper. Each diameter should be converted to a radius using $d = r/2$ before using the formula πr^2 to calculate the area where there is no growth on and around each disc.



Safety

1% VirKon solution should be made up shortly before use in the practical. Wear eye protection and nitrile protective gloves when removing impervious surfaces from the tray/bowl of 1% VirKon. Concentrated VirKon solutions and the solid are irritant to skin and eyes. 1% VirKon solution is presently not considered hazardous.

Ethanol (IDA) is hazardous, harmful and highly flammable.

Check before the practical that no student is taking immunosuppressive medication that may increase their risk of infection with bacteria. Warn students not to rub their eyes and to wash any splashes on skin immediately with water and soap. Make sure students wash their hands thoroughly before beginning the practical and again before leaving the laboratory.

Plates must be taped closed as shown in the worksheet to allow air in and discourage the growth of pathogenic bacteria. Never incubate plates above 25 °C, as this encourages growth of pathogenic bacteria. Secure the lids with additional tape before giving them to students, leaving a few gaps so that some oxygen can still enter and condensation can escape.

Sterilise all equipment before and after use with microorganisms.

Support: Work with students to discuss the answers to the questions. Students may need support with the calculations in step 2 of the results on the worksheet. Alternatively they could use a qualitative method of recording, such as photography.

Stretch: Remove the numbered questions from the worksheet and ask students to complete their own write-up.

Expected results

There should be a relationship between increasing concentration of antibiotic and increasing diameter of clear area around the disc. Or if comparing types of antibiotics, a comparison of the relative effectiveness of each (compared with the control) should be possible.

Course resources

Bio Students' sheet CP5

Equipment

per group: pre-poured agar plate with lid, bacterial culture in screw-top bottle (e.g. *Bacillus subtilis*, *Micrococcus luteus*), sterile pipette in wrapper, sterile spreader in wrapper, suitable container (e.g. wide-necked screw-top bottle) of 1% VirKon, two small filter paper discs of different antibiotic concentration or type (available pre-prepared from biological suppliers), sterile (e.g. autoclaved in foil) disc of filter paper (same diameter as antibiotic discs), sticky tape, marker pen, forceps, ethanol (IDA), Bunsen burner and heat-resistant mat, ruler

Optional (if students pour their own plates): Petri dish with lid, screw-top bottle of sterile liquid nutrient agar kept in water bath at 50 °C (for different antiseptics), small filter paper discs dipped in different antiseptics (for plant extracts), see Exploring 1 *SB5g Plant defences*



Sample question

This example is taken from the sample assessment material, paper 1BIO/1BH and 1BIO/1BF. Parts of the question overlap between the higher and foundation tier. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams and includes some application of specific maths skills.

2 *Streptococcus pyogenes* is a bacterium that causes communicable infections.

(a) Scientists tested the ability of two antiseptics to kill *Streptococcus pyogenes* bacteria.

They spread *Streptococcus pyogenes* bacteria on two agar jelly plates and placed a small disc of filter paper containing antiseptic in the centre of each dish.

Figure 3 shows the results of the test after 24 hours of incubation.

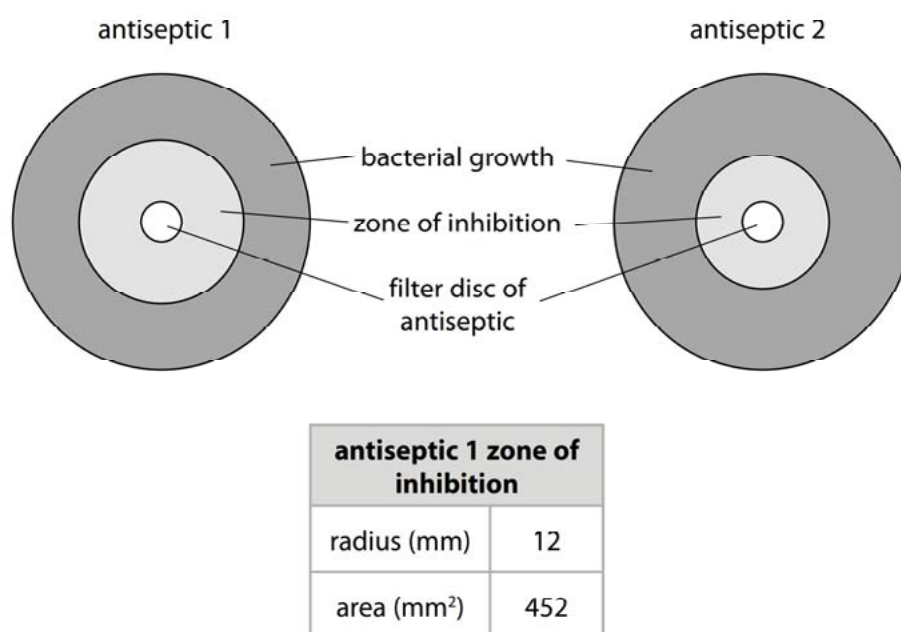


Figure 3

(i) Calculate the area of the zone of inhibition for antiseptic 2.

Give the answer to 3 significant figures.

($\pi = 3.14$)

(3)

zone of inhibition for antiseptic 2 = mm²



Question number	Answer	Additional guidance	Mark
2(a)(i)	- radius 10 mm $\pm$ 1 mm (1) - area = πr^2 (1) - area 314 (mm²) (1) answer must be to 3 significant figures	if radius outside range but area calculated max 2 marks award full marks for correct numerical answer without working	(3)

This question requires students to recall the equation needed to calculate the area of a circle, which is a required maths skill. They need to measure the radius of the zone of inhibition and use this to calculate the total area.

(ii) Explain which antiseptic is the most effective.

(2)

Question number	Answer	Additional guidance	Mark
2(a)(ii)	An explanation that combines identification via a judgement (1 mark) to reach a conclusion via justification/reasoning (1 mark): - antiseptic 1 has a larger zone of inhibition (1) - so more of <i>Streptococcus pyogenes</i> have been killed (1)	ecf from (a)(i)	(2)

For this question, students need to use their answer from part (i) and compare it to the value in the table for antiseptic 1. They need to be able to explain that a larger zone of inhibition indicates that more bacteria have been killed because the antiseptic is more effective.



- (iii) After the bacteria were spread on the plates, both plates were incubated for 24 hours at 37°C.

Give a reason why the plates were incubated at 37°C.

(1)

Question number	Answer	Additional guidance	Mark
2(a)(iii)	to provide optimal growth conditions	<i>S. pyogenes</i> grow at body temperature	(1)

This question asks for a reason why a particular variable needs to be controlled.

- (iii) Both plates were incubated for 24 hours.

State **two** other variables the scientist would need to control during the test.

(2)

1

2

Question number	Answer	Mark
8(a)(iii)	Any two of the following points: - volume of antiseptic (1) - incubation temperature (1) - same type of agar (1) - amount of bacteria (1)	(2)

For this question, students need to identify two other variables that would need to be controlled during the investigation to ensure valid conclusions can be made.

- (b) The wire loop used to spread bacteria on an agar plate was heated in a Bunsen burner flame before being used.

(i) Explain why this aseptic precaution was used.

(2)

.....

.....

.....

.....



Question number	Answer	Mark
8(a)(iii)	Any two of the following points: • volume of antiseptic (1) • incubation temperature (1) • same type of agar (1) • amount of bacteria (1)	(2)

For this question, students need to identify two other variables that would need to be controlled during the investigation to ensure valid conclusions can be made.

(b) The wire loop used to spread bacteria on an agar plate was heated in a Bunsen burner flame before being used.

(i) Explain why this aseptic precaution was used.

(2)

Question number	Answer	Mark
8(b)(i)	An explanation that combines identification – understanding (1 mark) and reasoning/justification – understanding (1 mark): • the Bunsen burner flame kills all microorganisms on the loop (1) • so only the desired bacteria are transferred to the loop/no unwanted microorganisms spread to the agar plate (1)	(2)

This question is based on a knowledge specification point but this knowledge is also likely to have been gained by completing the core practical. Students need to explain why killing any bacteria initially on the wire loop is necessary.



(ii) State **one** additional aseptic technique which would have been used for this investigation.

(1)

Question number	Answer	Mark
8(b)(ii)	Any one from: • keep the lids on the agar plates after growth (1) • use agar sterilised in an autoclave first (1) • work close to a Bunsen flame to create an uplift (1)	(1)

The knowledge needed to answer this question will have been gained while completing the core practical.



Core practical 6: Light intensity and Photosynthesis

6.5 Core practical: Investigate the effect of light intensity on the rate of photosynthesis

Links to the specification content

- | | |
|-----|---|
| 6.1 | Describe photosynthetic organisms as the main producers of food and therefore biomass |
| 6.2 | Describe photosynthesis in plants and algae as an endothermic reaction that uses light energy to react carbon dioxide and water to produce glucose and oxygen |
| 6.3 | Explain the effect of temperature, light intensity and carbon dioxide concentration as limiting factors on the rate of photosynthesis |
| 6.4 | Explain the interactions of temperature, light intensity and carbon dioxide concentration in limiting the rate of photosynthesis |
| 6.6 | Explain how the rate of photosynthesis is directly proportional to light intensity and inversely proportional to the distance from a light source, including the use of the inverse square law calculation |

Introducing the practical

This practical allows students to investigate the effect of light intensity on the rate of photosynthesis. Algal balls are placed in hydrogen carbonate indicator at different distances from a light source. The indicator is sensitive to pH and varies depending on the concentration of CO₂ in the solution. The results can be compared with a standard set of solutions to determine the effect of light intensity on the rate of photosynthesis. This core practical allows higher-ability students to investigate the inverse square law for photosynthesis.

The practical uses algae immobilised in alginate beads, which could be prepared by technicians or by students to increase their practical skills knowledge. There are a number of variables that will need to be identified and controlled by the students during the investigation. A similar method could be used to investigate the effect of other limiting factors on the rate of photosynthesis, e.g. temperature, to enhance the students' understanding of both their theoretical knowledge and the core practical technique.

Link to GCSE Science 2011: 'Investigate how factors, including the effect of light intensity, CO ₂ concentration or temperature, affect the rate of photosynthesis' was a core practical in GCSE Biology 2011 Unit B2 Topic 2.



Questions you could ask to enhance learning and focus your students on important aspects of the practical:

- How can light intensity be measured?
- How can light intensity be calculated?
- What is the optimum temperature for this investigation?
- When should the algal balls be added to the indicator solution?
- What are the other variables that need to be controlled during the investigation?
- Why does algae work better than pondweed in this type of investigation?
- What are the benefits of using immobilised algae?
- Why does the rate of photosynthesis lead to a colour change in the indicator solution?
- Why is a tube of water placed between the light source and the tubes of indicator containing the algal balls?
- Why is a set of standard solutions used?
- What other methods can be used to measure the rate of photosynthesis?

Skills that are covered in the practical:

- Safe manipulation of apparatus
- Recognition and controlling of risks
- Careful measurements
- Collection and interpretation of quantitative data
- Use of an indicator solution

Maths skills:

- Application of the inverse square law for photosynthesis

**Your teacher may watch to see if you can...**

- follow instructions carefully
- work safely.

**Introduction**

Microscopic algae have cells that contain chloroplasts, like plant leaf cells. The algae can be trapped in jelly balls to make them easier to handle. You will put algal balls in an indicator that changes colour as carbon dioxide levels change. Under normal conditions the indicator is a red colour, but this changes to yellow at higher carbon dioxide **concentrations** and purple at lower carbon dioxide concentrations.

Aim

To find out how light intensity affects the **rate** of photosynthesis.

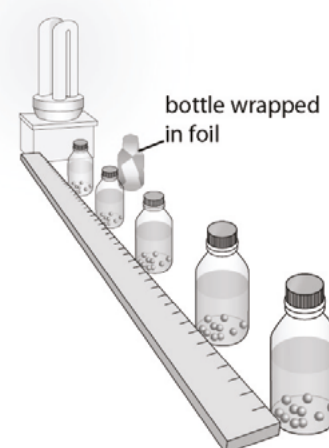
Method**Apparatus**

- | | |
|--------------------------------|-------------------------|
| • eye protection | • metre rule |
| • bijou bottles and caps | • measuring cylinder |
| • beaker of algal balls | • kitchen foil |
| • hydrogen carbonate indicator | • clock/stop clock |
| • lamp and heat filter | • plastic forceps/spoon |

**Safety**

- Wear eye protection.
- Wash your hands after setting up the experiment.
- Avoid touching the hot lamp.

- Decide the different distances you are going to use between the algae and the lamp. For each distance you will need one clear glass bottle. You will also need one extra bottle.
- Add 10–15 algal balls to each bottle.
- Add the same volume of indicator solution to each bottle and put on the bottle caps.
- Your teacher will have a chart or a range of bottles showing the colours of the indicator at different pHs. Compare the colour in your tubes with this pH range to work out the pH at the start.
- Set up a heat filter between the lamp and where you will place your tubes. The heat filter is a water-filled bottle or other clear container. Take great care not to spill water near the lamp.
- Cover one bottle in kitchen foil, so that it is in the dark.
- Place your bottles at measured distances from the lamp. Put the bottle covered in kitchen foil next to the bottle that is closest to the lamp.
- Turn on the lamp and time 60 minutes (or longer).
- Compare the colours of all your bottles with those of the pH range bottles.
- Record the pHs of the solutions in your bottles in a suitable table.
- For each bottle, calculate the change in pH per hour. Add these calculations to your table.

**Considering your results/conclusions**

- Plot your results on a scatter graph.
- Describe the pattern shown on your graph and explain why this pattern is observed.
- H** Explain whether the pattern on your graph obeys the **inverse square law**.

Evaluation

- What is the purpose of the tube covered in foil?

Name _____ Class _____ Date _____ **Recording your results**

- 1 Record your results in this table.

Distance from lamp to bottle (cm)		pH at start	pH at end	Rate of photosynthesis (change in pH/hour)

Considering your results/conclusions

- 2 a For each bottle, calculate the rate of photosynthesis as the change in pH per hour.

change in pH = pH at end – pH at start

$$\text{rate} = \frac{\text{change in pH}}{\text{time (in hours)}}$$

- b Use your calculations to complete the last column of the table above.
- 3 Plot your results on a scatter graph. Plot the variable that you have changed (the independent variable) on the horizontal axis. Plot the rate of photosynthesis on the vertical axis.
- 4 a Describe the pattern shown on your graph. _____
- _____
- b Explain why this pattern is observed. _____
- _____
- _____

Evaluation

- 5 Complete the missing words in the sentences below to explain the point of the tube covered in foil.

The part of an experiment in which the _____ variable is not applied is called the control.

A control is used to check that the _____ variable has an effect (and that the effect is not due to another variable). In this experiment, the independent variable is the _____ intensity. The control is the _____. We know that the independent variable has a direct effect on the final pH of the indicator because _____

_____.



Sciences Bio CP6 Factors that affect photosynthesis

Objectives

- B6.3** Explain the effect of temperature, light intensity and carbon dioxide concentration as limiting factors on the rate of photosynthesis.
- B6.4** **H** Explain the interactions of temperature, light intensity and carbon dioxide concentration in limiting the rate of photosynthesis.
- B6.5** *Investigate the effect of light intensity on the rate of photosynthesis.*
- B6.6** **H** Explain how the rate of photosynthesis is directly proportional to light intensity and inversely proportional to the distance from a light source, including the use of the inverse square law calculation.

Maths requirements

- 2d** Understand the principles of sampling as applied to scientific data.
- 2f** Understand the terms mean, mode and median.
- 2g** Use a scatter diagram to identify a correlation between two variables.
- 3a** Understand and use the symbols: =, <, <<, >>, >, ∞, ~.
- 3b** Change the subject of an equation.
- 4a** Translate information between graphical and numerical form.
- 4b** Understand that $y = mx + c$ represents a linear relationship.
- 4c** Plot two variables from experimental or other data.
- 4d** Determine the slope and intercept of a linear graph.

Learning outcomes

-  **SB6.3** Recall what is meant by a rate of reaction.
-  **SB6.3** Describe the effects of temperature, light intensity and carbon dioxide concentration on the rate of photosynthesis.
-  **SB6.3** Explain the effects of limiting factors of photosynthesis.
-  **SB6.4** **H** Explain the effects of more than one factor on the rate of photosynthesis.
-  **SB6.6** **H** Describe how light intensity and rate of photosynthesis are related.
-  **SB6.6** **H** Explain why the rate of photosynthesis is inversely proportional to the distance of a light source.



Exploring

1. Core practical – Light intensity and photosynthesis

This is a Core practical for Combined Science. Details of the experimental method are given in the Student Book and also on Students' sheet CP6(How light intensity effect photosynthesis). Supply students with enough algal balls for them to be able to add 10–15 to each bottle that they prepare. This will yield results in about an hour.

This practical, using immobilised algae in alginate balls, is based on a method developed by Science & Plants for Schools, and is described on its website. The practical can also be found on the National Centre for Biotechnology Education (NCBE) website. The NCBE also sells kits with all the materials needed for this practical (note that the algal balls themselves cannot be purchased and need to be made). Other suppliers are available.

You need a three- to four-week-old culture of algae (Science & Plants for Schools recommends unicellular *Scenedesmus quadricauda*). To make algal balls, take about 50 cm³ of dark green algal culture and allow it to settle, then pour off the liquid at the top leaving about 10 cm³ of concentrated culture. An alternative is to centrifuge 50 cm³ of the suspension. Use a syringe to add 2.5 cm³ of 2–3% sodium alginate solution to a 50 cm³ beaker, add the concentrated algal solution and stir well. Add 20 cm³ of 2% calcium chloride solution to another 50 cm³ beaker. Pour the algal solution into a 12.5 cm³ fine-nosed syringe (with the plunger removed) and allow drops to fall into the calcium chloride solution. Leave for about 15 minutes for the balls to stabilise, then remove the balls from the solution using a tea strainer and wash with distilled water. Keep moist and in daylight until ready to use.

You also need hydrogen carbonate indicator solution. This should be a cherry red colour and equilibrated with the carbon dioxide in the air by bubbling air through the solution using a fish tank bubbler in a well-ventilated prep room. You can buy the solution ready made or you can make it up. Instructions for making the solution and a chart showing the colours of the indicator can be found on the Science & Plants for Schools or NCBE websites. A better alternative is to prepare a range of bottles showing the indicator at different pHs. Full instructions for how to do this are also given on the Science & Plants for Schools and NCBE websites.

It is expected that most students will follow the instructions on page 1 of Worksheet SB6b.1 and answer the questions at the end of the sheet.

**! Safety**

Wear eye protection. Wash hands after setting up the experiment. Avoid touching the hot lamp.

Support: Students follow the instructions on page 1 of Worksheet SB6b.1 and then fill in their results, draw conclusions and so on using page 2 of the worksheet. Students could use a smartphone with a light meter app and measure the light intensity at each distance from the lamp. Plotting scatter diagrams/graphs of light intensity against change in pH will show a more obvious pattern than plotting the distance. A spare column in the table on page 2 of the worksheet allows students to record light intensities.

Stretch: Challenge students to follow the method on page 1 of the worksheet and then write up their results, conclusions and evaluation without help (consider removing the directed questions from the bottom of page 1 of the worksheet). Various skills sheets can assist students with this. Encourage students, as part of their evaluation, to suggest how they could alter this practical to investigate another factor that affects photosynthesis (e.g. temperature, light wavelength).

Expected results

Students should find a clear pattern in their results: the further away the light source (the lower the intensity of the light), the less quickly the pH falls.

Course resources

Bio Students' sheet CP6

Equipment

To make algal balls: three- to four-week-old culture of algae (e.g. *Scenedesmus quadricauda*) (refer to the Science & Plants for Schools website or supplier's instructions for culture method), 2–3% w/v sodium alginate solution (this needs to be left on a magnetic stirrer overnight, for the sodium alginate to fully dissolve in the water – do not be tempted to warm it), 2% w/v calcium chloride solution (0.18 mol dm^{-3}), 12.5 cm^3 fine-nosed syringe, two 50 cm^3 beakers, retort stand and clamp, tea strainer, stirring rod/plastic spoon. Make enough algal balls to allow 10–15 to be placed in each of the bottles made up by students.

For students: bijou bottles and caps (one for each distance to be investigated and one for a control), small beaker containing algal balls in distilled water (enough for 10–15 balls to be added to each bottle), hydrogen carbonate indicator (equilibrated with carbon dioxide from the air), plastic forceps or plastic spoon (to transfer balls), light source (flood lamp with filament bulbs in excess of 60 W or compact fluorescent bulb equivalents, 15–22 W – these can be shared between groups; note that 40–60 W power rated bulbs can also be used but are unlikely to provide results in under an hour), heat filter for the lamp (a water-filled medical flat bottle/square/rectangular glass vase/beaker), measuring cylinder, metre rule, kitchen foil (to cover one bijou bottle), stop clock, graph paper.

Optional: light meters or light meter smartphone apps



Sample question

These examples are taken from the sample assessment material, paper 1BI0/2BF and 1BI0/2BH. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams and includes some application of specific maths skills.

A scientist investigates the effect of light intensity on photosynthesis.

He sets up the equipment shown in Figure 1.

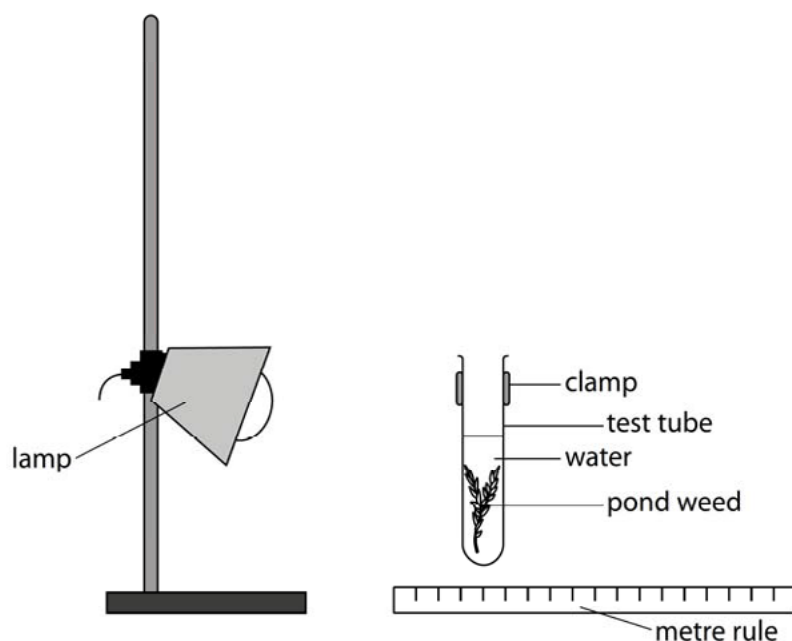


Figure 1

He places the lamp 10cm from the test tube and records the number of bubbles produced in five minutes.

He repeats the procedure with the lamp at a distance of 20cm and 30cm away from the test tube.

The scientist wants to repeat his investigation at each distance.



(b) (i) State **three** variables that should be kept constant to improve the results.

(3)

1

.....

2

.....

3

Question number	Answer	Mark
1(b)(i)	- temperature of water (1) - start each experiment with the same amount of carbon dioxide (1) - start each experiment with the same amount of water (1)	(3)

This part of the question uses an alternative practical for measuring the effect of light intensity on the rate of photosynthesis. The students can use the knowledge they have gained while completing the core practical to identify the variables that need to be controlled in this investigation.

The scientist noticed that the temperature of water near the light increased.

(ii) Give **one** improvement the scientist could make to reduce the effect of this increase in temperature.

(1)

.....

.....

Question number	Answer	Mark
1(b)(ii)	Any one improvement from: - use a heat shield (1) - use a water bath (1)	(1)

This part of the question requires students to recognise the importance of a heat shield during investigations that measure the effect of light intensity on the rate of photosynthesis.



(c) Figure 2 shows the results of the investigation.

distance (cm)	number of bubbles counted			
	test 1	test 2	test 3	mean
10	42	37	44	41
20	23	24	22	
30	10	11	12	11

Figure 2

(i) Calculate the mean result for a distance of 20cm.

(1)

Question number	Answer	Additional guidance	Mark
1(c)(i)	$\frac{23+24+22}{3}$ (1) $69 \div 3 = 23$ (1)	award full marks for correct numerical answer without working	(1)

This part of the question is a simple mean calculation using data from the table.

The number of bubbles counted for test 2 at 10cm was anomalous.

(ii) State how the scientist could deal with this anomaly.

(1)

Question number	Answer	Mark
1(c)(ii)	repeat the reading to get concordant results/calculate the mean without the anomalous result	(1)

This part of the question draws on skills for the analysis of data that students will gain from completing many of the core practicals.



(iii) Give a conclusion about the effect of light intensity on photosynthesis.

(1)

(Total for Question 1 = 8 marks)

Question number	Answer	Mark
1(c)(iii)	{as light intensity decreases/distance from the lamp increases} the rate of photosynthesis decreases	(1)

This part of the question requires students to interpret the data in the table to produce a simple conclusion.



- 5 A scientist investigated the effect of light intensity on the rate of photosynthesis of the aquatic *Cabomba* plant.

A lamp was used as a source of light. The lamp was placed at different distances (d) from the *Cabomba* plant, and the number of bubbles produced in 60 seconds was counted.

The number of bubbles produced in 60 seconds was used to calculate the rate of photosynthesis.

The light intensity was then calculated using the inverse square law $\left(\frac{1}{d^2}\right)$.

Figure 10 shows the scientist's results.

distance (d) of lamp from <i>Cabomba</i> (cm)	light intensity (arbitrary units)	bubbles produced in 60 seconds
5	0.0400	79
10	0.0100	21
15	0.0044	12
20	0.0025	7
25		5
30	0.0011	4

Figure 10

- (a) (i) Calculate the light intensity when the lamp is 25 cm from the *Cabomba* plant.

(2)

light intensity = arbitrary units

Question number	Answer	Additional guidance	Mark
5(a)(i)	$25 \times 25 = 625$ (1) $1 \div 625 = 0.0016$ (1)	award full marks for correct numerical answer without working	(2)

This part of the question requires students to use the equation given in the stem of the question to calculate the light intensity.



- (ii) Use information from Figure 10 to describe the effect of light intensity on the rate of photosynthesis.

(2)

Question number	Answer	Mark
5(a)(ii)	An answer that combines points of interpretation/evaluation to provide a logical description: - as light intensity decreases the rate of photosynthesis also decreases (1) - after 20 cm away when light intensity appears to have little effect on the rate of photosynthesis (1)	(2)

The students need to interpret the data given in the table to describe the effect of light intensity on the rate of photosynthesis. They need to recognise two features from the data, the initial decrease in the rate of photosynthesis and then a levelling off of the rate as light intensity decreases.

- (iii) Give another method of measuring light intensity rather than calculating it.

(1)

Question number	Answer	Mark
5(a)(iii)	use a light meter/lux meter	(1)

The knowledge required to answer this part of the question could have been gained during a discussion of different techniques that could be used during the core practical.



- (iv) The scientist counted the number of bubbles produced by the *Cabomba* plant.

Another scientist stated that this was not the best method of measuring the volume of gas produced.

Explain how you could improve the method to measure the volume of gas released more accurately.

(2)

Question number	Answer	Additional guidance	Mark
5(a)(iv)	An explanation that combines identification – improvement of the experimental procedure (1 mark) and justification/reasoning which must be linked to the improvement (1 mark): • collect the gas/oxygen produced in a graduated gas syringe (1) • to reduce the errors generated when counting bubbles which maybe of different sizes (1)	accept alternative gas collection method with measuring cylinder and beehive shelf accept leave the apparatus for a longer amount of time	(2)

This part of the question draws on the skills students will have gained by completing core practicals. They should be able to analyse given methods and suggest improvements.



(b) Explain what would happen to the levels of gas produced if the light intensity decreased to 0.0001 arbitrary units.

(2)

Question number	Answer	Mark
5(b)	An explanation that combines identification via a judgment (1 mark) to reach a conclusion via justification/reasoning (1 mark): - the volume of gas produced would decrease to below four bubbles (1) - because light is needed for photosynthesis (1)	(2)

This part of the question requires students to analyse data they have been given and make a prediction as to the outcome if the data is extrapolated.



Core practical 7: Respiration rates

8.11 Core practical: Investigate the rate of respiration in living organisms

Links to the specification content

- | | |
|------|--|
| 8.9 | Describe cellular respiration as an exothermic reaction which occurs continuously in living cells to release energy for metabolic processes, including aerobic and anaerobic respiration |
| 8.10 | Compare the process of aerobic respiration with the process of anaerobic respiration |

Introducing the practical

There are many factors which can effect respiration rate. This core practical uses a respirometer to investigate the effect of temperature on the rate of respiration in small organisms. There are a number of different organisms that can be used in the respirometer. In addition, this could also be done using germinating peas. The respirometer measures the rate of oxygen uptake and uses soda lime to absorb the carbon dioxide released. The apparatus needs to be carefully assembled and care must be taken at all times to ensure that the living organisms are treated appropriately.

The core practical offers many opportunities for students to develop their practical skills and knowledge. There are a number of variables which need to be controlled and a control tube is needed as a comparison. The investigation measures the distance moved by a coloured liquid along a capillary tube and this information can be used to calculate a rate of oxygen uptake by the organisms at different temperatures. The practical also provides the opportunity to discuss the ethics of using living organisms in scientific investigations.

Link to GCSE Science 2011: 2.1 'Recall that respiration is a process used by all living organisms that releases the energy in organic molecules' and 2.4 'Demonstrate an understanding of how aerobic respiration uses oxygen to release energy from glucose and how this process can be modelled using the word equation for aerobic respiration' in GCSE Biology 2011 Unit B2 Topic 2.
--



Questions you could ask to enhance learning and focus your students on important aspects of the practical:

- Why is soda lime used in the investigation?
- Why must soda lime be handled carefully?
- What variables need to be controlled during the investigation?
- What are the ethical and safety issues that arise from using living organisms in investigations?
- Why do the tubes containing the organisms need to be left in a water bath for 5 minutes before the rate of oxygen consumption is measured?
- How can the distance that the coloured liquid moves be used to determine the rate of oxygen uptake?
- What temperatures are appropriate to use during the investigation?
- Why is a control tube included in the investigation?
- Why should measurements be repeated at each temperature?
- What are the benefits of using thermostatically controlled water baths?
- How should anomalous results in the data be dealt with?
- How can the final data be presented?

Skills that are covered in the practical:

- Safe handling and manipulation of living organisms
- The ability to manipulate apparatus and use a respirometer
- Measuring and recording information carefully
- Careful use of a water bath
- Safe handling of chemical reagents

Maths skills:

- Mean calculations
- Calculating rates of oxygen uptake
- Identification of anomalous results
- Plotting a scatter graph

**Your teacher may watch to see if you can...**

- work carefully with living organisms
- make accurate measurements.

**Aim**

To investigate the effect of temperature on the rate of **aerobic respiration** in invertebrates.

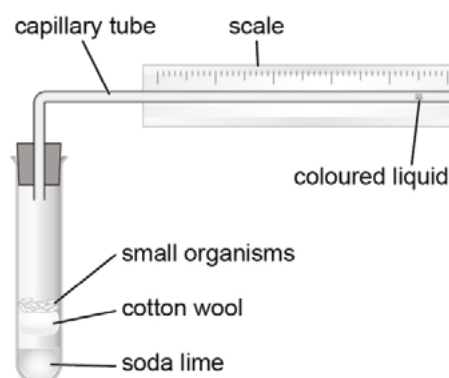
Method**Apparatus**

- boiling tube containing soda lime (and a cotton wool plug)
- capillary tube and bung
- weighing boat
- stop clock
- water baths at different temperatures
- millimetre scale
- small organisms
- coloured liquid

Safety

Treat living things with care.
Wash your hands after the practical.
Soda lime is corrosive.

- Collect a boiling tube with some soda lime in it, held in place with cotton wool. The soda lime absorbs carbon dioxide. Soda lime is corrosive, so do not handle it. The cotton wool is to protect you and the organisms.
- Carefully collect some of the small organisms in a weighing boat.
- Gently shake the organisms out of the container and into the boiling tube.
- Insert the bung and capillary tube, as shown in the diagram.
- Set up a control tube (without the organisms).
- Place both tubes into a rack in a water bath at a preset temperature. It is best to tilt the rack slightly so that the capillary tubes hang over the side of the water bath at an angle.
- Wait for five minutes to let the organisms adjust to the temperature of the water bath (maximum 40 °C).
- Hold a beaker of coloured liquid to the ends of the capillary tubes, so that liquid enters.
- Mark the position of the coloured liquid in the tubes and time for five minutes.
- Mark the position of the coloured liquid again, and measure the distance travelled.
- Repeat the experiment at different temperatures. Use the same number of organisms each time.

**Recording your results**

- Record your results in a neat table.

Considering your results/conclusions

- Plot your results on a suitable chart or graph.
- Use your chart or graph to draw a conclusion. Explain your conclusion.



Name _____ Class _____ Date _____ 

Recording your results

- 1 Record your results in the table below.

Temperature (°C)	Distance moved by the coloured liquid in the tube containing organisms (mm)	Distance moved by the coloured liquid in the control tube (mm)

Considering your results/conclusions

- 2 Plot your results on a scatter diagram.

- 3 a What was the independent variable in this investigation? _____
- b What was the dependent variable? _____
- c State one control variable described in the method. _____
- d Explain why the variable you gave in **c** needs to be controlled.

- e Describe the relationship between the temperature and rate of aerobic respiration.

- f Suggest an explanation for this relationship. (*Hint*: think about the effect of temperature on chemical reactions.)

Evaluation

- 4 The organisms in the tube are respiring aerobically.

- a What gas are they using up? _____
- b What gas are they producing? _____
- c Explain why the gas you named in **b** does not collect in the tube. _____



Objectives

- B8.9** Describe cellular respiration as an exothermic reaction which occurs continuously in living cells to release energy for metabolic processes, including aerobic and anaerobic respiration.
- B8.10** Compare the process of aerobic respiration with the process of anaerobic respiration.
- B8.11** *Core Practical: Investigate the rate of respiration in living organisms.*

Maths requirements

- 1a** Recognise and use expressions in decimal form.
- 2a** Use an appropriate number of significant figures.
- 2f** Understand the terms mean, mode and median.
- 4a** Translate information between graphical and numeric form.
- 4c** Plot two variables from experimental or other data.

Learning outcomes

-  **SB8.9** Explain why organisms need to respire.
-  **SB8.9** Recall the word equation for aerobic respiration.
-  **SB8.9** Recall the word equation for anaerobic respiration in humans.
-  **SB8.9** Explain why respiration is an exothermic process.
-  **SB8.10** Compare aerobic and anaerobic respiration.



Exploring

1. Respiration rates

This practical forms part of the core practical requirement of the specification. It is supported by the information on Students' sheet CP7 (*Rates of Respiration*) and in the Student Book.

Students follow the instructions on Worksheet SB8e.1 and use a simple respirometer to investigate the effect of temperature on the rate of aerobic respiration in some small invertebrates. Instructions for the practical and questions are also found on *SB8e Core practical – Respiration rates* in the Student Book.

A variety of organisms can be used in the respirometers, including mealworms, waxworms and blowfly larvae (maggots are best). Between 5 and 10 g of the organisms works well. It is best if students use fresh organisms for each temperature tested. Students can simply use the number of organisms as a control variable, although more able students should be encouraged to measure the masses of organisms used.

The suggested range of temperatures is 20–35 °C. Classroom management is easier if water baths are prepared at different temperatures within this range and then students choose which of two or three to try. Encourage students to work together to decide between the groups which temperatures they will investigate, to ensure an even spread of data, which can then be pooled and analysed as a class set.

It is envisaged that most students will follow the method on page 1 of the worksheet and answer the directed questions at the bottom of the sheet.

Safety

Living organisms must be handled with care.

Students must wash their hands after completing this practical.

Soda lime is corrosive. Do not allow students to handle this.

Support: Go through the parts of the apparatus carefully with students, explaining the purpose of the soda lime (to absorb carbon dioxide so that gases are only being used up and no gases from respiration are being allowed to take their place). Also explain that as the oxygen is used up, the volume of the gases in the respirometer will reduce, which in turn will allow atmospheric pressure to push the air bubble further along the tube. Students can fill in their results and draw conclusions using the scaffolded questions on page 2 of the worksheet.

Stretch: Encourage students to measure the masses of the organisms used and to use these values to calculate respiratory rate in terms of oxygen use per minute per gram of living material. Some students may be given the diameter of the glass tubing and be challenged to calculate the actual volume of oxygen used (the volume of a cylinder is given by $V = \pi r^2 h$), and to use this to give their results using the units $\text{mm}^3 \text{ min}^{-1} \text{ g}^{-1}$.



Students should be able to record their results, present their data and draw conclusions without help. (Consider removing the directed questions at the bottom of page 2 of the worksheet before printing/photocopying.)

Expected results

Students should find a clear increase in the rate of respiration with temperature. This is largely due to the fact that temperature speeds up chemical reactions by increasing the mean speed of the particles involved.

Course resources

Bio Students' sheet CP7

Equipment

respirometer (consisting of a boiling tube containing a spatula of soda lime, held in place with cotton wool, capillary tube, cored bung, millimetre scale), small invertebrates (e.g. waxworms, mealworms, blowfly larvae), electric water baths set at different temperatures in the range 20–35 °C, coloured liquid (100 cm³ water, enough food dye for a strong colour, and five drops of washing-up liquid), weighing boat, stop clock
Optional: balance, paint brush (to move organisms), graph paper



Sample question

This example is taken from the sample assessment material, paper 1BI0/2BH and. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams and includes some application of specific maths skills.

6 Figure 11 shows the equipment used for measuring respiration in peas.



(Source: Martin Shields/Science Photo Library)

Figure 11

- Respirometer A contains germinating peas.
- Respirometer B contains peas that are not germinating.
- Respirometer C contains glass beads.

All three respirometers are placed in a water bath at 25 °C for 30 minutes.

The reduction in oxygen levels in each respirometer is measured using a data logger.

(a) Explain why the respirometers are placed in a water bath at 25 °C.

(2)

Question number	Answer	Mark
6(a)	An explanation that combines identification – understanding (1 mark) and reasoning/justification – understanding (1 mark): • same temperature to act as control (1) • to provide the optimum temperature for enzyme action in the peas (1)	(2)

This question requires an explanation as to why temperature needs to be controlled in this investigation. The students need to link controlling temperature to enzyme activity.



- (b) A student recorded the change in oxygen levels in the germinating peas over a 30-minute period.

The results are shown below.

A 10 mins (−0.8) ml, 20 mins (−1.6) ml, 30 mins (−2.4) ml

B 10 mins (−0.1) ml, 20 mins (−0.1) ml, 30 mins (−0.1) ml

C No change

- (i) Complete the table for these results.

(2)

Question number	Answer	Additional guidance	Mark																
6(b)(i)	- headed table with units (1) - accurately completed table (1) <table border="1"> <thead> <tr> <th></th><th>A</th><th>B</th><th>C</th></tr> </thead> <tbody> <tr> <td>O₂ used /ml at 10 mins</td><td>0.8</td><td>0.1</td><td>0.0</td></tr> <tr> <td>O₂ used /ml at 20 mins</td><td>1.6</td><td>0.1</td><td>0.0</td></tr> <tr> <td>O₂ used /ml at 30 mins</td><td>2.4</td><td>0.1</td><td>0.0</td></tr> </tbody> </table>		A	B	C	O ₂ used /ml at 10 mins	0.8	0.1	0.0	O ₂ used /ml at 20 mins	1.6	0.1	0.0	O ₂ used /ml at 30 mins	2.4	0.1	0.0	negative values do not need to be shown if table heading states oxygen used/lost accept time in row 1 as an alternative	(2)
	A	B	C																
O ₂ used /ml at 10 mins	0.8	0.1	0.0																
O ₂ used /ml at 20 mins	1.6	0.1	0.0																
O ₂ used /ml at 30 mins	2.4	0.1	0.0																

This question requires students to understand how scientific data should be presented in a results table including the use of units in the header.



- (ii) Calculate the rate of oxygen consumption per second for the results in respirometer A.

(2)

..... ml/second

Question number	Answer	Additional guidance	Mark
6(b)(ii)	$2.4 \div (30 \times 60)$ (1) $= 0.0013$ (ml/second) (1)	accept $1.6 \div (20 \times 60)$ accept $0.8 \div (10 \times 60)$ award full marks for correct numerical answer without working maximum one mark if no unit conversion	(2)

This question requires students to calculate the rate of oxygen consumption per second by using data from the investigation. It requires the conversion of minutes to seconds in the rate calculation.

- (iii) Explain why respirometer A has the highest rate of oxygen consumption.

(2)

.....

.....

.....

.....

Question number	Answer	Mark
6(b)(iii)	An explanation that combines identification – application of knowledge (1 mark) and reasoning/justification – application of understanding (1 mark): - the peas in respirometer A are germinating so using up oxygen (1) - during the process of respiration to release energy for growth (1)	(2)

This question requires students to use their knowledge on respiration to explain the results of the investigation. They should recognise that germination is an active process and therefore requires energy which is released during respiration.



(c) Some respirometers read the movement of a bubble along capillary tubing.

Carbon dioxide can affect the measuring of oxygen used in this type of respirometer.

State a chemical that could be placed in the respirometer that would stop carbon dioxide affecting the experiment.

(1)

Question number	Answer	Additional guidance	Mark
6(c)	Any one improvement from: soda lime (1) • cotton wool soaked with potassium hydroxide (1)	accept other relevant chemical that would remove carbon dioxide	(1)

This question requires students to demonstrate their knowledge of the core practical method by knowing that soda lime is used to absorb carbon dioxide.



Core practical 8: Quadrats and transects

9.5 Core practical: Investigate the relationship between organisms and their environment using field-work techniques, including quadrats and belt transects

Links to the specification content

9.6	Explain how to determine the number of organisms in a given area using raw data from field-work techniques, including quadrats and belt transects
-----	---

Introducing the practical

The core practical investigates the effect of shade on the abundance of low growing plants. It uses a belt transect to measure the abundance of plants and also requires students to measure light intensity. Students should start measuring the abundance of plants and light intensity in open ground and finish their measurements in the shade of a tree. It would also be possible to repeat this investigation measuring the effect of a different abiotic factor, such as water, to enhance understanding of the techniques involved. The practical will teach students how a quadrat is used. It will also make them consider other factors such as how frequently a measurement should be taken along a transect and methods for recording and presenting data.

Link to GCSE Science 2011: 2.22 'Investigate the relationship between organisms and their environment using fieldwork techniques' and 2.23 'Investigate the distribution of organisms in an ecosystem, using sampling techniques including a pooters, b sweep nets/pond nets, c pitfall traps, d quadrats, and measure environmental factors including e temperature, f light intensity, g pH' were core practicals in GCSE Biology 2011 Unit B2 Topic 2.



Questions you could ask to enhance learning and focus your students on important aspects of the practical:

- What variables need to be considered when measuring light intensity?
- How many plants species should be measured?
- How long should the belt transect be?
- How frequently along the transect should a measurement be taken?
- How does a belt transect differ from a line transect?
- Which plants on the edges of the quadrat should be included in the count?
- How can the results be recorded and presented?
- What factors, other than light intensity, could affect the distribution of organisms along the belt transect?
- How might the results differ at different times of the day?
- How might the results differ at different times of the year?
- How would the method be modified to measure the abundance of a particular species across a large area?

Skills that are covered in the practical:

- The use of a quadrat and belt transect
- Consideration of variables
- Recording and presentation of quantitative data
- Consideration of the environment during fieldwork

Maths skills:

- Presentation of multiple sets of quantitative data



Your teacher may watch to see if you can:

- work efficiently
- follow safety guidance.

Introduction

A transect is used to study the **distribution** of organisms and how it is affected by changes in environmental conditions. A **belt transect** places quadrats at regular intervals along the transect line to sample the organisms.

Aim

To investigate the distribution of a species using a transect and quadrats.

Method

Apparatus

- long tape measure (at least 20 m) and pegs at each end
- quadrat (e.g. 50 × 50 cm square)
- apparatus for measuring suitable **abiotic factors**, e.g. light sensor and recorder, soil humidity sensor, small bags for collecting soil samples for nutrient testing in the lab, trowel, anemometer (wind speed measurer)
- optional: identification charts, labels for bags, pencil



Safety

Follow any safety guidance related to the working area.

Consider the safety aspects of your chosen site, such as poisonous plants, animal faeces or open water, and take appropriate precautions while working.

- If your teacher hasn't told you where to place the transect, look for somewhere that shows obvious variation in environmental conditions, such as from bright light to deep shade under a tree, or from an area that shows heavy trampling to an area where few people walk.
- Decide which environmental factors you will measure and how you will measure them.
- Peg out the tape measure along the ground to form the transect line.
- Measurements should be made at regular intervals along the transect line (as shown in the diagram). Decide on your measurement intervals, which may depend on how long the line is, and how much time you have to record information.
- Place the top left-hand corner of the quadrat at a measurement point on the transect line.
- Measure the environmental factors at that point and record them. Any soil samples should be collected using a trowel and placed in a sealed bag, one for each sample quadrat. Label each bag clearly to identify its position along the transect.
- Record the abundance of your selected organisms in the quadrat.
- Repeat steps **E–G** at each measurement point along the transect.
- In the lab, carry out suitable tests on any soil samples and record the results.





Name _____ **Class** _____ **Date** _____ 

Recording your results

- 1 In the space below draw a table to record the abundance of the organisms you sampled at each point along the transect line, as well as the environmental factor at each sample site.

- 2 Display your results in a suitable chart or graph.

Considering your results/conclusions

- 3 Along the transect, describe the change in distribution of your chosen organism.

- 4 Along the transect, describe the change in your chosen environmental factor.

- 5 Describe any correlation between the change in distribution of the organism and the change in the environmental factor.

- 6 Suggest one reason why the change in the environmental factor could have caused the change in distribution of the organism.

Evaluation

- 7 Suggest an experiment that you could do in the lab to test whether the environmental factor you measured actually affects the organism as you suggest in question 6.



It can take a very long time to count all the organisms in a **population** in a large area. A **quadrat** is used to take **samples**. A quadrat is a square frame of a particular size, such as 50×50 cm.

The position of a quadrat in an area is selected randomly. This can be done by dividing the whole area into a grid and selecting grid coordinates using a random number generator. The quadrat is placed at the coordinates.

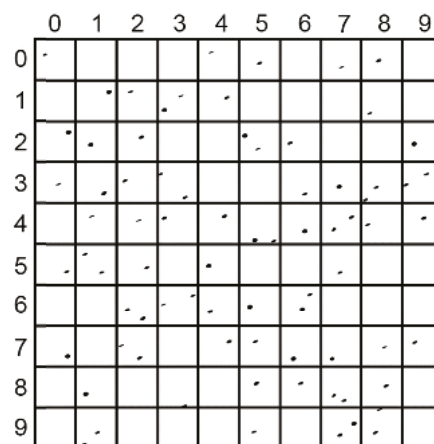
The number of individuals of the study species inside the quadrat is recorded. The quadrat is then placed at another set of random coordinates, and the number of individuals is recorded again. The number of times this process is repeated often depends on the time available. However, it is best to take at least five samples.

To estimate the total population size, you add up the total number of organisms in all the quadrats. You also calculate the total area of all the quadrats and the total area of the study area. The formula for calculating an estimate of the population size is:

$$\text{estimated population size} = \text{total number of organisms in samples} \times \frac{\text{total area of study area}}{\text{total area of quadrats}}$$

- 1 Use the information above to write a method for an investigation to estimate the population size of daisy plants on a school field.
- 2 Write an apparatus list for your method.
- 3 For which of these organisms would quadrat sampling not work? Give a reason for your answer.
dandelion plants blackbirds shellfish attached to rocks ground beetles
- 4 Give a reason why quadrats should be randomly placed when taking samples to estimate population size.
- 5 The diagram shows the position of daisy plants on a school field. Each square is 1 m by 1 m.

- a Use random numbers to select 10 pairs of coordinates. These are your 10 sample squares on the grid.
- b Count and record the number of plants in each of your sample squares.
- c Use your results, and the formula above, to calculate an estimate for the size of the daisy plant population on the field. Show your working.



Extra challenge

- 6 The total number of daisies in the field above is 78.
 - a Compare your value from question 5c with the actual total, suggesting a reason for any difference.
 - b Using further samples, test the statement above that it is best to take at least five samples to get a reasonable estimate of population size.



Objectives

- B9.2** Explain how communities can be affected by abiotic factors including
a temperature, light, water, pollutants
- B9.5** *Core Practical: Investigate the relationship between organisms and their environment using field-work techniques, including quadrats and belt transects.*
- B9.6** Explain how to use raw data from field-work techniques, including quadrats and belt transects.

Maths requirements

- 1c** Use ratios, fractions and percentages.
- 2c** Construct and interpret frequency tables and diagrams, bar charts and histograms.
- 2d** Understand the principles of sampling as applied to scientific data.

Learning outcomes

-  **SB9.2** Give examples of abiotic factors.
-  **SB9.2** Explain how communities are affected by abiotic factors (temperature, light, water, pollutants).
-  **SB9.6** Explain how to investigate the effect of abiotic factors on the distribution of organisms using belt transects.



Exploring

1. Quadrats and transects – Core practical

This practical forms part of the core practical requirement of the specification, looking at the effect of the environment on the distribution of organisms. It is supported by the information on *Students' sheet CP8(Using transect and Quadrat)* and in the Student Book.

Worksheet SB9c.1 provides a practical using a transect and quadrat to measure the effect of environmental factors on the distribution of organisms. This practical can be adapted to any available example of changing distribution related to environmental change, such as the distribution of plants between shade and bright light, or from a well-trampled area to an area of little trampling, or the distribution of seaweed or shellfish on a rocky seashore from low to high tide. If the practical work is to be done on the school playing fields, consider a preparatory session on the field to provide students with the opportunity to decide where best to take samples.

A preparatory discussion will be needed to identify which environmental factors to measure and how best to measure and record them. It may also help if students become familiar with the organisms they will record, from identification charts, before they go into the field. Suggest they focus on recording details of only one or two species. Note that abundance can be measured by counting individuals within the quadrat, or estimating percentage coverage of the quadrat for species such as grass that are very common. Alternatively, students could use the ACFOR (abundant, common, frequent, occasional, rare) method of scoring. (Information on this can be found on the Internet.) If soil samples are taken, students will need time in the lab to carry out analysis, for example using nutrient test kits.

Question 2 on the worksheet requires students to consider the best way to display the results. This will depend on how the data was recorded, as some (discontinuous data) will need presenting as a bar chart and some (continuous data) as a line graph. Some students may be able to combine results on one set of axes, using different scales and a key for each factor measured. Other students may need to draw separate charts or graphs for each factor. In the latter case, encourage them to align the x-axis of each chart, to make comparison easier.

Support: During the practical work, make sure that students are clear about what to measure and record, as well as how to set out the transect and quadrats for sampling. When students are recording and analysing results, work with them to draw up the record table and chart(s). Discuss the remaining questions before students complete the rest of the sheet.

Stretch: Students could plan and carry out their investigation without the worksheet. Challenge students to consider all the environmental factors that might affect the distribution of the organisms. For example, a tree with a large canopy not only creates shade, but also may reduce the amount of precipitation reaching the ground, as well as removing more moisture and nutrients through its roots. This will probably result in students not being able to identify which factor has the greatest effect, but should lead to deeper understanding of the interaction between biotic and abiotic factors in an ecosystem.



Safety

Carry out a full risk assessment of the area where sampling will take place and make sure students are fully aware of safety issues and how to tackle them.

Expected results

If a clear change in distribution of an organism along the transect was measured, students should be able to associate that with a change in value of an appropriate environmental factor (e.g. abundance of daisies is greater where light intensity is greater or trampling less). Note, this may not always occur, because an environmental factor that was not measured may be controlling distribution more than the factors measured. In this case, discuss with students what else might be causing the distribution, and ask them to suggest how they would test their ideas.

Course resources

Bio Students' sheet CP8a

Equipment

long tape measure (at least 20 m) with pegs at each end to hold it firmly in place on the ground, quadrat (e.g. 50 cm², or 1 m² if recording larger plants/seaweed), apparatus for measuring suitable abiotic factors (e.g. light sensor and recorder, soil humidity sensor, small bags for collecting soil samples for nutrient testing in the lab, trowel, soil nutrient testing kit, wind speed measurer), identification charts, labels for bags, pencil



Objectives

- B9.1** Describe the different levels of organisation from individual organisms, populations, communities, to the whole ecosystem.
- B9.3** Describe the importance of interdependence in a community.
- B9.6** Explain how to determine the number of organisms in a given area using raw data from field-work techniques, including quadrats.

Maths requirements

- 1c** Use ratios, fractions and percentages.
- 2c** Construct and interpret frequency tables and diagrams, bar charts and histograms.
- 2d** Understand the principles of sampling as applied to scientific data.

Learning outcomes

-  **SB9.1** State what is meant by the ecological terms community, population and habitat.
-  **SB9.1** Give examples of an ecosystem, a community, a population and a habitat.
-  **SB9.1** Describe the organisation of the components of an ecosystem (including populations, communities, habitats and abiotic factors).
-  **SB9.3** Describe how the interdependence of organisms in an ecosystem allows their survival.
-  **SB9.6** Explain how to estimate population size, including the use of quadrats.

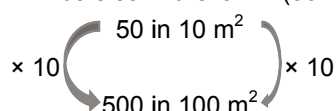
Before starting, consider using rapid-fire quick questions to check and secure basic knowledge and understanding from recent lessons (examples are given in the Quick Quiz below). The quiz can be done as a whole class and should take no more than a couple of minutes.

You can also ask students to complete the Progression questions at the top of the Progression Check sheet and to score their confidence levels. This gives students their own baseline with which to measure their own learning during the lesson.

The **ALDS** presentation *SB9a Ecosystems objectives* contains the Objectives, Learning outcomes and Progression questions and allows confidence levels to be monitored. The Quick Quiz is available as the **ALDS** presentation *SB9a Quick Quiz*.

Quick Quiz

- Which term describes organisms, such as plants or algae, that make their own food? (producers)
- Why can plants and algae make their own food? (cells contain chlorophyll/carry out photosynthesis)
- Which term describes organisms that get their food by eating other organisms? (consumers)
- Which term describes animals that eat plants or algae? (herbivores/primary consumers)
- Which term describes animals that kill and eat other animals? (predators/carnivores/secondary consumers)
- Name a type of diagram that shows the feeding relationships between organisms. (food chain/food web)
- Which scientific term means all the organisms and the environment they interact with? (ecosystem)
- Which scientific term means all individuals of the same species living in a particular area? (population)
- Which piece of equipment could be used to investigate the number of plants in an area? (quadrat)
- Fifty daisy plants have been found in a 10 m² sample of a 100 m² lawn. Estimate the total population of daisies in the lawn. ($50 \times 100 / 10 = 500$)





Starters

1. Building a food web

Ask students to name organisms that might be seen locally and write these on the board. You may need to prompt for plants such as grass or trees, or organisms that are not usually visible (such as those in the soil or in water). If needed, add familiar organisms such as blackbird, earthworm, rabbit, fox.

Students should work in pairs to arrange the organisms into a food web. Take examples of food chains in their webs, and expect students to justify their links.

2. Ecosystem concept map

Write the word ecosystem on the board. Ask students to work in pairs or small groups to construct a concept map on scrap paper around the word. They should discuss suitable words and agree how best to link them. (If needed, suggest some suitable words, such as: food chain, food web, population, producer, consumer, environment, light, water.) When pairs have at least six linked words, they should compare their map with a neighbouring group's map and justify what they've added. Students should keep their concept maps for adding to at the end of the lesson.

Equipment

scrap paper

Exploring

1. Estimating population size

Worksheet SB9a.1 provides work on estimating population size. Students may have carried out this kind of investigation in Key Stage 3, in which case this will provide revision. If not, consider carrying out the methods that students come up with in question 1 as fieldwork, if there is time and the opportunity.

To complete the sampling question on the sheet, students will need a method of randomly generating whole numbers from 0 to 9. This can be done, for example, using a 10-sided die (recording 0 every time a 10 is rolled) or a random number app. Discuss with students how they should use each pair of numbers to place the quadrat, for example, the first number should be read on the horizontal scale, and the second number on the vertical scale. To help answer question 4 about random sampling, ask students which squares on the field grid they would choose to sample and why. Discuss the impact of choosing 'interesting' areas for sampling, or areas that might be easier to get to.

If students are well experienced with the counting method used in the worksheet, ask students how the method could be adapted for species where it is difficult to identify separate individuals (e.g. grass plants) or for comparing the importance of different species in an area (as some plants have much larger leaves than others). In this case, the percentage cover of a quadrat by the species is measured. Examples of the use of this method can be found on the Internet.

Support: Students may need help working out how to use pairs of random numbers to identify the correct squares to sample. They may also need support when carrying out the calculation in question 5c.

Stretch: The Extra challenge question at the bottom of the sheet will help students evaluate their results. For part b, if students are unsure how to test the statement, hint at the answer by asking them how much variation in estimates they would expect if they calculated from only one square/sample each time.



Safety

If fieldwork is carried out, carry out a full risk assessment of the area where sampling will take place and make sure students are fully aware of safety issues and how to tackle them.

Course resources

AAP: Worksheet SB9a.1

**Equipment**

method for generating random whole numbers between 0 and 9, e.g. 10-sided die or a random number app, calculator

Optional for fieldwork: quadrat, plant identification guide, ruler

2. Ecosystem research

Students should work in pairs or small groups to carry out research on a specific ecosystem. Either provide examples of ecosystems on the board for students to select from or check that students have chosen something reasonable before they start. Suitable examples include: a coral reef, a rainforest, a desert, African savannah, polar ocean. Students should identify organisms in the ecosystem and then show how they are grouped into populations and communities. From these they should create a food web to identify feeding relationships. Results could be displayed on a poster or in a presentation.

Skills Sheets RC3 and RC4 could support this task.

Support: Give students a familiar ecosystem (e.g. UK farmland or garden) and the names of a selection of organisms in it to get started.

Stretch: Students should choose an ecosystem with a challenging 'storyline', such as coral reefs that are dying or rainforest that is being replaced with palm oil plantations. Students can then focus on the impact of ecosystem-level destruction and the importance of interdependence.

Course resources

AAP: Optional: Skills Sheets RC3 and RC4

Equipment

access to the Internet

Explaining**1. Student Book SB9a Ecosystems**

Work through the Student Book pages, answering the questions up to the checkpoint.

Students should be familiar with food webs and categories of feeding from Key Stage 3. These can be simply revised using examples from the food web in diagram D.

Students may need practice in defining the terms ecosystem, habitat, community and population, because these are often used incorrectly in non-scientific text.

The Core Practical statement in the GCSE specification includes the use of quadrats to measure abundance, and the use of quadrats along transects to measure the effect of the environment on distribution. Exploring 1 provides practice on estimating abundance. The belt transect work is covered on *SB9c Abiotic factors and communities* in the Student Book.

The **ALDS** presentation *SB9a Ecological terms* covers ecological definitions in a visual way.

Support: Work with students to answer the questions.

Stretch: Students could write dictionary definitions for each bold word on the Student Book pages for the topic.

Course resources

ALDS: Presentation *SB9a Ecological terms*

SB: *SB9a Ecosystems*

2. What might happen if ...?

Display a food web on the board. Suitable examples can be found on the Internet. If possible, use an example where a change to the community has been made or is being considered, for example introducing a non-indigenous species or reintroducing a species (such as wolves in the Scottish Highlands or beavers in Devon).

Use the food web to ask questions of the form 'What might/will happen if ...' to identify how changes will impact on other populations in the community. For example, what might happen to the population size of deer if wolves



are reintroduced to the area? Encourage students to explain their answers and to take each answer a step further by considering what effect the change to the population size of deer (or equivalent) will have on a different population. Use the answers to get across the idea of interdependence in an ecosystem and its importance in a food web. Note that this prepares for some of the work on biotic factors in topic *SB9d Biotic factors and communities* and the impact of non-indigenous species in *SB9g Biodiversity and humans*.

Support: Only ask questions that consider species that directly affect each other (e.g. a predator and one species of prey).

Stretch: Students could think up their own questions using the food web and test each other. Take examples from around the class to find really challenging examples of interactions.

Equipment

food web from the Internet, such as where a non-indigenous species has been introduced to the community or there is suggestion of reintroducing a species

Checkpoint

Ask students to complete the Assessment and Feedback sections of the Progression Check sheet for this topic. Or revisit the Progression questions on *SB9a Ecosystems* in the Student Book and assess whether students feel more confident about answering them. Less confident students should use the 'Strengthen' activity. Students who demonstrate good understanding should move on to the 'Extend' activity.

Strengthen

Ask students to work in pairs or small groups to answer question S1 in the Student Book and/or the questions on Worksheet SB9a.2. Question 1 on the worksheet provides scaffolding for answering question S1. The remaining questions on the worksheet cover other objectives for this topic. Students should compare their completed answers with another pair or group, to check for any errors.

As an alternative or extension, students could add to the concept maps that they produced in Starter 2, using what they have learned in the lesson. They should compare their additions with other students to make sure they have included all the key points.

Course resources

AAP: Worksheet SB9a.2

SB: *SB9a Ecosystems*

Equipment

calculator

Extend

Ask students to work in pairs to discuss question E1 in the Student Book. If needed, hint at what the diagram does not include, or suggest other species that are not included, such as pond skaters, midge larvae or water lilies. They will need to consider how other species might fit in the food web, and how they are affected by pond snails, either directly or indirectly. They should compare their answer with another pair, to identify any similarities and differences in their explanations.

Course resources

SB: *SB9a Ecosystems*

Reflect

Ask students to answer the exam-style question at the end of *SB9a Ecosystems* in the Student Book. Encourage students to think about what each mark is for before constructing an answer. You could point out that the question requires a description, not an explanation, so no reason is needed in the answer.



Homework

Homework 1

Worksheet SB9a.3 is suitable for homework and contains straightforward questions about this topic. Question 3 is a calculation, which some students might find challenging.

Support: Check that students understand the questions before completing the sheet.

Course resources

AAP: Worksheet SB9a.3

Equipment

calculator

Homework 2

Worksheet SB9a.4 is suitable for homework and contains more challenging questions about this topic.

Stretch: Students complete the Extra challenge question at the end of the sheet.

Course resources

AAP: Worksheet SB9a.4

Equipment

calculator



Sample question

This example is taken from the sample assessment material, paper 1BI0/2BF. The commentary below outlines how the skills students will have gained by carrying out the practical may be shown in the final exams

- 6** (a) A scientist wanted to estimate the number of earthworms in a field using a quadrat.

The scientist placed the quadrats at random on the surface of the area being sampled and then watered the area with a very dilute solution of mustard.

This causes the earthworms to come to the surface to be counted.

- (i) Give a reason why the quadrats were placed at random.

(1)

Question number	Answer	Mark
6(a)(i)	To obtain a representative sample of the field (1)	(1)

This question looks at the use of a quadrat to measure abundance of organisms across an area and requires students to know why random sampling is required.



(b) A student wants to estimate the number of daisy plants in a 500 m² field.

She uses a 1 m² quadrat to sample the field.

Figure 9 shows the results for the number of daisy plants counted in six areas sampled with the quadrat.

sample number	number of daisy plants	mean diameter of daisy plants / cm
1	5	7
2	2	2
3	6	9
4	3	3
5	4	5
6	4	6

Figure 9

(i) Calculate the mean number of daisy plants for the six samples.

(1)

mean number of daisy plants =

Question number	Answer	Mark
6(b)(i)	$\frac{5+2+6+3+4+4}{6} = 4$ (1)	(1)

This question requires the calculation of a mean, which is one of the required maths skills.



- (ii) Describe how the student could use this calculated mean to estimate the total number of daisy plants in this field.

(2)

Question number	Answer	Mark
6(b)(ii)	An answer that combines the following points of understanding to provide a logical description: • divide the field area by the quadrat size (1) • multiply by the mean number of daisies (1)	(2)

This question is based on the specification statement and requires students to know how to determine the number of organisms in a given area using raw data from field-work techniques. Students will be required to write plans for possible practical work in the exams.

Sample 2 was taken in an area where there were many overhanging trees.

- (iii) Explain how these trees may have affected the distribution of daisy plants growing in this area.

(2)

Question number	Answer	Mark
6(b)(iii)	An explanation that combines identification – application of knowledge (1 mark) and reasoning/justification – application of understanding (1 mark): • less daisy plants are likely to be growing in this area (1) • because the trees would cause lower light levels for photosynthesis/lower mineral levels for growth/less water available for photosynthesis (1)	(2)

This question is based on the knowledge the students will have acquired by doing the core practical activity. It needs the candidates to extract the data about sample 2 from the table and then explain why there are fewer daisies growing in the shade.



- (iv) Give **two** abiotic factors that could affect the distribution and size of daisies growing in this field.

(2)

(Total for Question 6 = 11 marks)

Question number	Answer	Mark
6(b)(iv)	Any two of the following: Temperature (1) pH (1) pollutants (1) water (1)	(2)

To answer this question, candidates need to know two abiotic factors which affect the growth of plants.



Appendix 1

Department for Education: apparatus and techniques list

	BIOLOGY
1	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, temperature, volume of liquids and gases, and pH
2	Safe use of appropriate heating devices and techniques including use of a Bunsen burner and a water bath or electric heater
3	Use of appropriate apparatus and techniques for the observation and measurement of biological changes and/or processes
4	Safe and ethical use of living organisms (plants or animals) to measure physiological functions and responses to the environment
5	Measurement of rates of reaction by a variety of methods including production of gas, uptake of water and colour change of indicator
6	Application of appropriate sampling techniques to investigate the distribution and abundance of organisms in an ecosystem via direct use in the field
7	Use of appropriate apparatus, techniques and magnification, including microscopes, to make observations of biological specimens and produce labelled scientific drawings
	Separate science only
8	Use of appropriate techniques and qualitative reagents to identify biological molecules and processes in more complex and problem-solving contexts, including continuous sampling in an investigation.



Appendix 2

Core practical mapping

The table on the following pages shows how each core practical in biology offers opportunities for students to develop some of the mathematical skills and how the practicals map to the practical techniques in Appendix 1.

Biology

Biology Core Practical	Practical technique								Mathematical skills
	1	2	3	4	5	6	7	8	
1. Investigate biological specimens using microscopes, including magnification calculations and labelled scientific drawings from observations (1.6)	✓		✓				✓		1d Make estimates of the results of simple calculations 2a Use an appropriate number of significant figures 2h Make order of magnitude calculations 3b Change the subject of an equation
2. Investigate the effect of pH on enzyme activity (1.10)	✓		✓		✓			✓	1a Recognise and use expressions in decimal form 1c Use ratios, fractions and percentages 2a Use an appropriate number of significant figures 2b Find arithmetic means 2g Use a scatter diagram to identify a correlation between two variables 4a Translate information between graphical and numeric form 4d Determine the slope and intercept of a linear graph 4e Draw and use the slope of a tangent to a curve as a measure of rate of change



Biology Core Practical	Practical technique								Mathematical skills
	1	2	3	4	5	6	7	8	
3. Investigate the use of chemical reagents to identify starch, reducing sugars, proteins and fats (1.13B)		✓	✓		✓			✓	None
4. Investigate osmosis in potatoes (1.16)	✓		✓		✓				1a Recognise and use expressions in decimal form 1c Use ratios, fractions and percentages 2b Find arithmetic means 2g Use a scatter diagram to identify a correlation between two variables 4a Translate information between graphical and numeric form
5. Investigate the effects of antiseptics or antibiotics or plant extracts on microbial cultures (5.18B)	✓	✓	✓				✓		1a Recognise and use expressions in decimal form 1c Use ratios, fractions and percentages 2a Use an appropriate number of significant figures 2c Construct and interpret frequency tables and diagrams, bar charts and histograms 3a Understand and use the symbols: =, <, <<, >>, >, α, ~ 3c Substitute numerical values into algebraic equations using appropriate units for physical quantities 4a Translate information between graphical and numeric form 5c Calculate areas of triangles and rectangles, surface areas and volumes of cubes.
6. Investigate the effect of light intensity on the rate of photosynthesis (6.5)	✓	✓	✓	✓	✓				1a Recognise and use expressions in decimal form 1c Use ratios, fractions and percentages 2a Use an appropriate number of significant figures 2b Find arithmetic means

**GCSE (9–1) Sciences: Core practical guide**

Biology Core Practical	Practical technique								Mathematical skills
	1	2	3	4	5	6	7	8	
									2d Understand the principles of sampling as applied to scientific data 2g Use a scatter diagram to identify a correlation between two variables 3a Understand and use the symbols: =, <, <<, >>, >, α , ~ 4a Translate information between graphical and numeric form 4c Plot two variables from experimental or other data 4d Determine the slope and intercept of a linear graph
7. Investigate the rate of respiration in living organisms (8.11)	✓		✓	✓	✓				1a Recognise and use expressions in decimal form 1c Use ratios, fractions and percentages 2a Use an appropriate number of significant figures 2b Find arithmetic means 2d Understand the principles of sampling as applied to scientific data 2g Use a scatter diagram to identify a correlation between two variables 3a Understand and use the symbols: =, <, <<, >>, >, α , ~ 4a Translate information between graphical and numeric form 4c Plot two variables from experimental or other data 4d Determine the slope and intercept of a linear graph
8. Investigate the relationship between organisms and their environment using field-work techniques including quadrats and belt transects (9.5)	✓			✓		✓	✓		1c Use ratios, fractions and percentages 2b Find arithmetic means 2c Construct and interpret frequency tables and diagrams, bar charts and histograms 2d Understand the principles of sampling as applied to scientific data 3a Understand and use the symbols: =, <, <<, >>, >, α , ~



Appendix 3

GCSE Sciences: Equipment list

The list below is for all core practicals in GCSE Combined Science and Separate sciences. The separate science equipment is draft, and will be updated with a final version on the Edexcel website soon.

Biology

Spec statement	Equipment needed (per group)
1.6 Investigate biological specimens using microscopes, including magnification calculations and labelled scientific drawings from observations	Microscope and light source beaker of 1% Virkon stain (e.g. methylene blue, iodine solution) paper towels plant material (e.g. onion, rhubarb) pipette eye protection sterile (autoclaved) wooden spatula/tongue depressor gloves plain glass microscope slide coverslip toothpick/cocktail stick [Note: equipment listed at the top is for a group and that listed after the break is for an individual (making a slide)]
1.10 Investigate the effect of pH on enzyme activity	test tube soluble starch 1% amylase solution (or 0.5% pancreatin solution) water bath 5 cm³ syringe or pipette, beaker eye protection 0.01 mol dm⁻³ iodine solution, well tray (spotting tile). hypochlorite (bleach) solution or 1% Virkon solution small beaker or other container for collecting saliva buffer solutions at set pH (using 0.2 mol dm⁻³ Na₂HPO₄ and 0.1 mol dm⁻³ citric acid or adding dilute hydrochloric acid and sodium hydrogen carbonate solution (prior to adding the amylase)
1.13B Investigate the use of chemical reagents to identify starch, reducing	food samples: powdered potato, full and/or low fat powdered milk, whey (protein) powder, powdered egg white (use commercially available albumen), powdered glucose; water, measuring cylinder, spatula, powdered foods, paper towels,



Spec statement	Equipment needed (per group)
sugars, proteins and fats	test tubes, racks and bungs, stirrer, iodine solution (1 g iodine in 100 cm³ 0.5 mol dm³ potassium iodide solution) in dropper bottle, Benedict's solution (prepared according to CLEAPSS Recipe card 11 [qualitative] or 12 [for quantitative measurements], Biuret solution (prepared according to CLEAPSS Recipe Sheet 15) in dropper bottle, Sudan III stain (dissolve 0.5 g dye in 70 cm³ ethanol [highly flammable] and 30 cm³ water, using a warm water bath and filter) in dropper bottle, water bath at 70 °C. (optional) icing sugar, hydrochloric acid, sodium hydroxide solution, water bath at 100 °C. Note: Sudan III test for lipids will now be optional. Emulsion test for lipids (using ethanol) is sufficient for core practical.
1.16 Investigate osmosis in potatoes	4 Potato strips four boiling tubes and rack (or beakers), waterproof pen, 550 g/dm³ sucrose solution forceps agar cubes containing sodium hydroxide and universal indicator or phenolphthalein (one cube each of side lengths 2 cm, 1 cm and 0.5 cm or an agar block large enough for students to cut their own cubes), 20 cm³ 0.1 mol/dm³ hydrochloric acid, 100 cm³ beaker forceps white tile knife stopclock or watch eye protection
5.18B Investigate the effects of antiseptics, antibiotics or plant extracts on microbial cultures	Petri dish with lid, of agar covered with a bacterial lawn (e.g. E.coli or Staphylococcus albus) prepared antibiotic discs in different concentrations sticky tape marker pen sterile forceps ethanol (IDA) incubator
6.5 Investigate the effect of light intensity on the rate of photosynthesis	pre-prepared algal (<i>Scenedesmus quadricauda</i>) balls (in a beaker of fresh distilled water) hydrogen carbonate indicator solution (cherry red colour (pH 8.4) and equilibrated with air) 5 - 8 small (bijou) bottles with caps (pre-washed in distilled water) metre rule lamp (with high light intensity, circa. 80 W incandescent or



Spec statement	Equipment needed (per group)
	equivalent CFL/LED) spatula (clean and washed in distilled water) kitchen foil access to a display of bottles showing the colours of the hydrogen carbonate at different pH
8.11 Investigate respiration in living organisms	small organisms (e.g. meal worms) 2 boiling tubes (containing 2 spatulas of soda lime held in place at the bottom of the tube with a plug of cotton wool) (1 tube for test, 1 for control) cored bung(s) (to fit into boiling tube) L-shaped capillary tube(s) (to fit into cored bung) ruler eye protection plastic 'weighing boat' beaker of water containing strongly coloured (e.g. with food dye) solution access to water baths at different temperatures, with boiling tube racks
9.5 Investigate the relationship between organisms and their environment	quadrat (e.g. 1 metre square) long tape measure (at least 20 m) with securing pegs equipment for measuring appropriate physical factors (e.g. thermometer, light meter, data recorder with light, moisture or temperature sensors, soil pH meter) clipboards recording sheets



Appendix 4 Mapping to lab book

The table below can be used to map between the core practicals in the lab book (which follow the teaching order) and the core practicals in the specification (which is the ordering used in this guide).

specification reference		lesson ref from schemes of work	numbering in this guide	published lab book numbering
Biology				
1.6	<i>Investigate biological specimens using microscopes including magnification calculations and labelled scientific drawings from observations</i>	<i>CB1b.1</i>	Core practical 1	Core practical 1
1.10	<i>Investigate the effect of pH on enzyme activity</i>	<i>CB1g.1</i>	Core practical 2	Core practical 2
1.13B	<i>Investigate the use of chemical reagents to identify starch, reducing sugars, proteins and fats</i>	<i>SB1f.1</i>	Core practical 3	
1.16	<i>Investigate osmosis in potatoes</i>	<i>CB1h.1</i>	Core practical 4	Core practical 4
5.18B	<i>Investigate the effects of antiseptics, antibiotics or plant extracts on microbial cultures</i>	<i>SB5k.1</i>	Core practical 5	<i>[Lab book 2]</i>
6.5	<i>Investigate the effect of light intensity on the rate of photosynthesis</i>	<i>CB6b.1</i>	Core practical 6	<i>[Lab book 2]</i>
8.11	<i>Investigate the rate of respiration in living organisms</i>	<i>CB8d</i>	Core practical 7	<i>[Lab book 2]</i>
9.5	<i>Investigate the relationship between organisms and their environment using field-work techniques, including quadrats and belt transects</i>	<i>CB9b</i>	Core practical 8	<i>[Lab book 2]</i>