INTERNATIONAL GCSE

Biology (2017)

CORE PRACTICAL GUIDE

Pearson Edexcel International GCSE in Science

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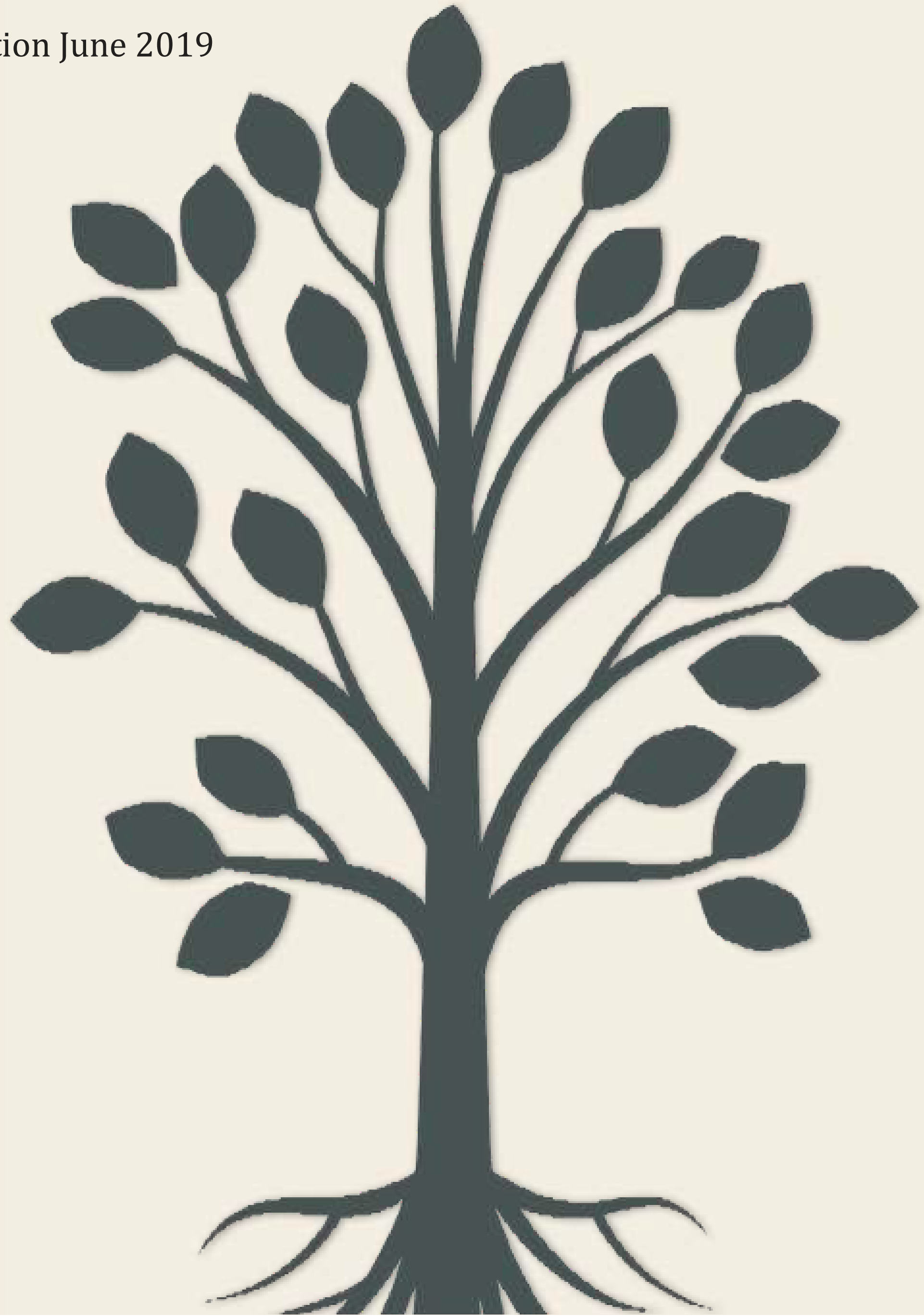

Core Practical Guide

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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.

Changes to practical requirements

There will not be any coursework in the International 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 work. In our exams, we will have questions on the core practicals in our specifications, as well as questions on other 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) that we have adhered to for consistency with the UK qualifications. If you carry out all the core practicals, you will automatically cover the apparatus and techniques list.

Approach to core practicals

In your day-to-day teaching, you should 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 techniques as a carousel, or split students into groups to take readings, there is no reason why you cannot still do this—if you have taken reasonable steps to ensure your students all acquire experience of carrying out that procedure or technique.

Assessment of practical work

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 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.

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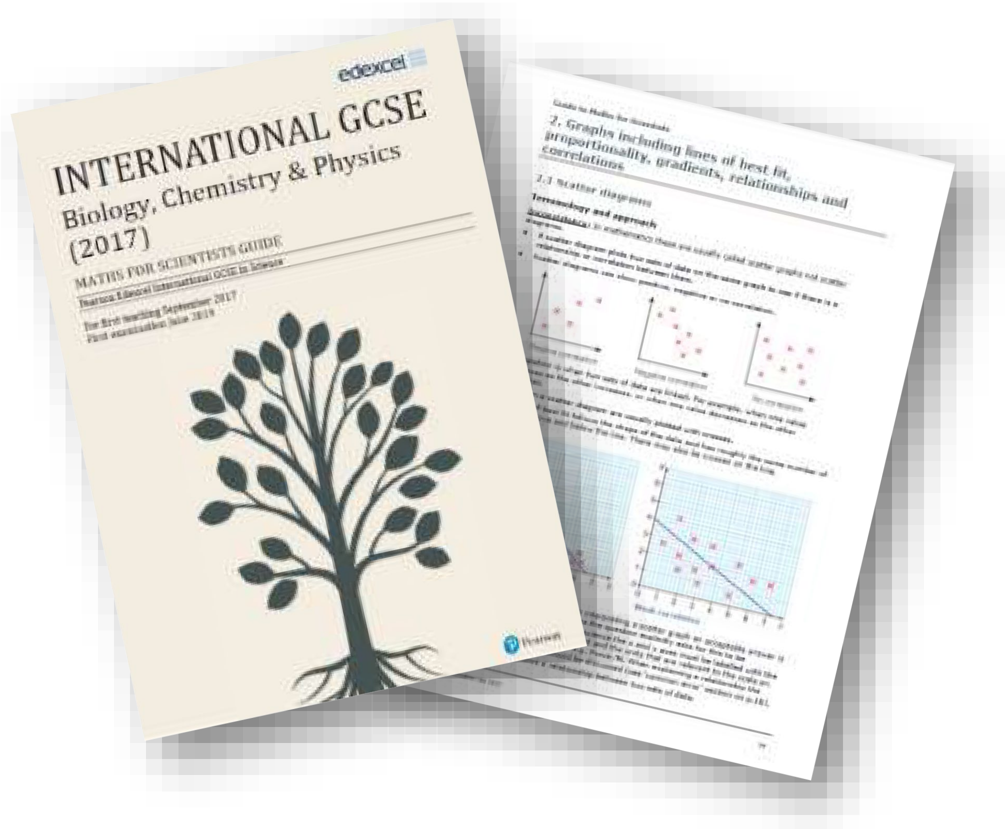
Maths skills

Practical activities offer a wide range of opportunities to cover 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.

N.B. 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.



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International GCSE Biology Practicals

There are 9 core practicals in the biology section of International GCSE Combined Science. International GCSE Biology covers the same 9 practicals as well as an additional 5, to make up 14 core practicals in total.

This section outlines each core practical and gives a brief description of each one. Then the guide goes through each core practical in turn, outlining how to carry out the practical, questions that could be asked, and the key skills involved (including maths skills).

Core practical descriptions

Note: **2.14B**, **2.33B**, **2.45B**, **2.58B** and **4.4B** are separate International GCSE Biology only

No.	Specification Reference	Description
1	*2.9 - Investigate food samples for the presence of glucose, starch, protein and fat*	Carry out the food tests shown below: 1. Identify starch by using potassium iodide 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
2	*2.12 - Investigate how enzyme activity can be affected by changes in temperature*	The digestion of starch by amylase can be used with students using potassium iodide solution to detect the presence of starch. Students are looking for the time at which the digestion mixture no longer contains any starch. This experiment can then be repeated at different temperatures. If the practical is first done at room temperature 25 °C, it can then be repeated by different groups within a class at a range of temperatures and data pooled.
3	***2.14B - Investigate how enzyme activity can be affected by changes in pH***	The digestion of starch by amylase can be used with students using potassium iodide solution to detect the presence of starch. Students are looking for the time at which the digestion mixture no longer contains any starch. This is carried out at different pHs using the same temperature.

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4	*2.17 - Investigate diffusion and osmosis using living and non-living systems*	Cubes of agar can be used with $KMnO_4$ or with food colouring as the diffusing substance to explore the relationship between size, volume, surface area and rate of diffusion. They can also look at changes in the mass and volume of potato tissue as it is immersed in solutions of various concentrations. They should also carry out a range of investigations using onion cells to look at osmosis, plasmolysis and turgor in plant cells viewed down a microscope. Visking tubing can also be used to look at osmosis and to demonstrate turgor and flaccidity.
5	*2.23 - Investigate photosynthesis, showing the evolution of oxygen from a water plant, the production of starch and the requirements of light, carbon dioxide and chlorophyll*	To explore the effect of light intensity on rate of photosynthesis students can use *Elodea* or *Myriophyllum scabratum.* Both work well in releasing sufficient oxygen to count bubbles or, if time allows, collect the gas in an inverted measuring cylinder and measure the volume of oxygen evolved per unit time. The other experiments investigate the effect of no light, no carbon dioxide and no chlorophyll on photosynthesis. These are all based on the same procedure of testing leaves for starch using potassium iodide solution on a leaf that has had its chlorophyll removed by boiling in ethanol. The leaves need to be destarched by placing in the dark for 24 hours so that they are free from starch at the start of the experiment.
6	***2.33B - Investigate the energy content in a food sample***	To investigate the energy content of food students can burn a known mass of the food using the heat energy released to heat a known volume of water.
7	*2.39 - Investigate the evolution of carbon dioxide and heat from respiring seeds or other suitable living organisms*	Respiring seeds can be placed in a thermos or vacuum flask and be shown to produce an increase in temperature in the flask if left for two or three days. Respiring seeds or blowfly larvae can be used to show that carbon dioxide is released during respiration.

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8	***2.45B - Investigate the effect of light on net gas exchange from a leaf, using hydrogen-carbonate indicator***	This investigation uses sodium hydrogen-carbonate indicator to show the changes in carbon dioxide concentration in the air surrounding leaves in different light conditions. Leaves of, for example, privet are placed in three of four boiling tubes containing a small volume of indicator. One tube is placed in bright light, one is wrapped in foil, one is wrapped in muslin and the tube without a leaf is also left in bright light.
9	*2.50 - Investigate breathing in humans, including the release of carbon dioxide and the effect of exercise*	This investigation uses limewater or hydrogen-carbonate indicator to compare the content of inhaled and exhaled air. The second part of the investigation is to compare breathing rates before and after exercise.
10	***2.58B - Investigate the role of environmental factors in determining the rate of transpiration from a leafy shoot***	This investigation uses a potometer to measure the rate of water uptake and therefore deduce water loss or transpiration from a leafy shoot. Each potometer can be used to collect readings in normal air, windy conditions, increased temperature, increased humidity, darkness and finally with half of the leaves removed.
11	*3.5 - Investigate the conditions needed for seed germination*	This investigation looks at the conditions needed for germination. Suitable conditions to investigate would be the temperature, availability of oxygen, and availability of water.
12	*4.2 - Investigate the population size of an organism in two different areas using quadrats*	This investigation looks at the method used to compare population size of a species in two different areas using quadrats.
13	***4.4B - Investigate the distribution of organisms in their habitats and measure biodiversity using quadrat***	This investigation extends the last practical (12) to look at how biotic and abiotic factors affect the distribution of organisms in their habitats. This requires students to measure abiotic factors, such as light intensity and link this to changes in distribution of species and changes in biodiversity.
14	*5.6 - Investigate the role of anaerobic respiration by yeast in different conditions*	This investigation gives students the chance to experiment on the factors that affect respiration in yeast. The rate of respiration can be measured either by collecting the carbon dioxide given off by downward displacement using a water filled measuring cylinder or by counting the bubbles. The investigation can have several alternative independent variables such as temperature, concentration of glucose or even using different sugars as a substrate.

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Core practical 1: Food tests

2.9 Core practical: Investigate food samples for the presence of glucose, starch, protein and fat

Links to the specification content

2.7	Identify the chemical elements present in carbohydrates, proteins and lipids (fats and oils)
2.8	Describe the structure of carbohydrates, proteins and lipids as large molecules made up from smaller basic units: starch and glycogen from simple sugars, protein from amino acids, and lipid from fatty acids and glycerol
2.24	Understand that a balanced diet should include appropriate proportions of carbohydrate, protein, lipid, vitamins, minerals, water and dietary fibre
2.25	Identify the sources and describe the functions of carbohydrate, protein, lipid (fats and oils), vitamins A, C and D, the mineral ions calcium and iron, water and dietary fibre as components of the diet
2.26	Understand how energy requirements vary with activity levels, age and pregnancy

Introducing the practical

The chemical test for glucose uses Benedict's solution, which is added to a sample of food and heated in a water bath at 80°C for 5 minutes. A colour change from blue to orange or brick red indicates the presence of a reducing sugar. The test can also be used to indicate the concentration of reducing sugar in the sample with green, yellow, orange and then brick red showing increasing levels of reducing sugar. Care should be taken not to boil the samples for too long in order to avoid any starch is hydrolysed into reducing sugars.

The chemical test for starch is to add a few drops of potassium iodide solution to the sample on a spotting tile. A blue-black colour indicates the presence of starch.

The test for protein is the Biuret test in which the reagent is added to the sample in a test tube and the presence of protein is indicated by a purple colour.

The test for lipid is usually the emulsion test. The food sample is placed in a test tube, a small volume of absolute ethanol is added, and the tube is shaken to dissolve any lipid in the alcohol. An equal volume of water is then added, and a cloudy emulsion indicates the presence of lipid.

These tests can be used on food samples or unknown powders or supplements to investigate their nutritional content.

Further information on the experiment can be found here from the TES website.

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Food tests

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

- Why should the food samples be heated for the same time in the test for glucose?
- Are these tests qualitative and how could we make them quantitative?
- How could we use these tests to indicate enzyme functioning?
- Do food substances contain more than one carbohydrate?
- What foods are good sources of each food molecule?

Skills that are covered in the practical:

- Selecting appropriate apparatus
- Measuring volumes of liquid accurately
- Observing and recording changes
- Producing appropriate results tables
- Ability to carry out investigation safely
- Analyse and interpret data to draw conclusions that are consistent with the evidence

Maths skills:

1C Use ratios, fractions, percentages, powers and roots (if using dilutions for a more quantitative analysis of Benedict's test)

Questions:

(iii) Describe an experiment you could carry out to compare the glucose concentration of samples of plasma and glomerular filtrate. **(4)**

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Mark scheme:

Question number	Answer	Mark
(b)(iii)	A description that makes reference to four of the following points: • Benedict's/equivalent (1) • heat (1) • red in high concentration of glucose (1) • orange/yellow-green in low concentration of glucose (1) • control volume of sample/time heated/temperature/ volume of Benedict's/equivalent (1)	**4**

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Core practical 2: Temperature and enzyme activity

2.12 Core practical: Investigate how enzyme activity can be affected by changes in temperature

Links to the specification content

2.10	Understand the role of enzymes as biological catalysts in metabolic reactions
2.11	Understand how temperature changes can affect enzyme function, including changes to the shape of the active site

Introducing the practical

The enzyme chosen depends upon student familiarity with different enzymes.

The digestion of starch by amylase can be used with students using potassium iodide to detect the presence of starch. If the concentrations and volumes are appropriate, then the digestion of the starch won't be too fast or too slow. Students are looking for the time at which the digestion mixture no longer contains any starch. This experiment can then be repeated at different temperatures.

If the practical is first done at room temperature 25°C, it can then be repeated by different groups within a class at a range of temperatures and data pooled.

Students will need to understand the relationship between the time taken for digestion to be completed and rate of reaction.

It is of course possible to use other enzymes such as catalase from potato with hydrogen peroxide as the substrate. In this case you can measure the rate of reaction directly by measuring the volume of oxygen evolved at each temperature.

Further information on the experiment can be found here on the Nuffield website.

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Temperature and enzyme activity

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

- What is the relationship between time taken for starch to be digested and rate of reaction?
- What are the independent, dependent and control variables in the investigation?
- How can we ensure that all the reagents are at the correct temperature during the experiment?
- What happens to the starch during the reaction?
- How could we use our knowledge of other food tests to check what has happened to the starch?
- How can the effect of temperature on enzyme action be explained?

Skills that are covered in the practical:

- Identify independent, dependent and control variables
- Selecting appropriate apparatus
- Measuring volumes of liquid accurately
- Observing and recording changes
- Producing appropriate results tables
- Ability to carry out investigation safely
- Analyse and interpret data to draw conclusions that are consistent with the evidence
- Assess the reliability of an experimental activity
- Evaluate data and methods considering factors that affect accuracy and validity

Maths skills:

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

4A Translate information between graphical and numerical form

4C Plot two variables (discrete and continuous) from experimental or other data

4D Determine the slope and intercept of a linear graph

Questions

A student investigates the effect of temperature on the rate of starch digestion by amylase. He carries out the first trial of his investigation at a room temperature of 20°C.

He carries out the following steps in his investigation

1 He puts one drop of iodine suspension into each of 12 wells on a spotting tile.
2 He then takes up 10 cm^3 of 10% starch suspension into a syringe.
3 He adds one drop of the starch suspension from the syringe to the first well in the spotting tile and records the colour change.
4 He rinses the outside of the syringe with water from a tap.

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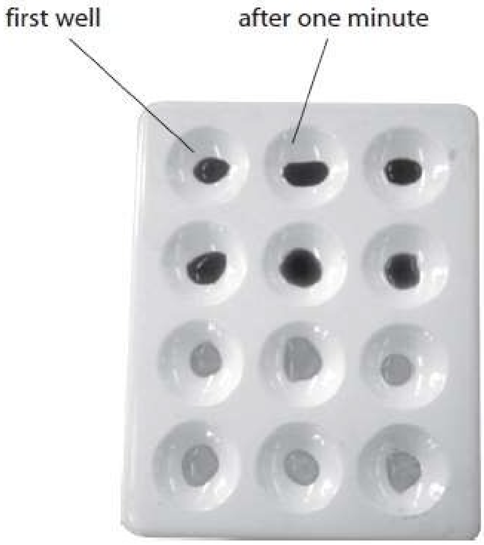
5 He then takes up exactly 5 cm^3 of 5% amylase suspension into the same syringe containing the 10% starch suspension.
6 He starts a stopwatch.
7 He then rocks the syringe containing the mixture gently backwards and forwards for one minute.
8 He adds one drop of the mixture from the syringe to the next well in the spotting tile and records the colour change.
9 He repeats this at intervals of one minute until he has added starch and amylase mixture to all the wells.
10 He then repeats steps 1–9 but this time he uses iodine, amylase and starch suspension that have been stored in a water bath at 40°C.
11 He also keeps the syringe containing the mixture in the water bath at 40°C between drops.

The photograph shows his results for 20°C at the end of the experiment when all the wells have mixture added.



(a) (i) Give one safety precaution the student should take when carrying out this investigation. (1)

____

(ii) How many minutes do the samples of mixture added to the spotting tile in the photograph represent? (1)

____

(b) Explain the purpose of the following steps in the student's experiment.
(i) step 4 (1)

____

____

(ii) step 7 (1)

____

____

(iii) step 11 (1)

(c) (i) Identify two variables that the student controls in his experiment. (2)

1

2

(ii) Name the independent variable that the student is investigating. (1)

(d) Using the photograph, explain how many minutes it took for the reaction to be completed at 20°C. (3)

(e) The results for the spotting tile at 40°C would be different from the trial carried out at 20°C.

(i) Describe how the appearance of the results will be different. (2)

(ii) Explain the difference in the appearance of the results. (2)

(Total for question = 15 marks)

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Mark scheme

Question number	Answer	Notes	Marks
(a) (i)	safety glasses / wear gloves ;	Ignore lab coat / tie hair back / eq	1
(ii)	11/ eleven;		1
(b) (i)	remove starch / solution from surface of syringe / eq;	Ignore get into syringe	1 1
(ii)	mix contents / mix amylase and starch / eq;	Mix alone = 0 Allow enzyme and starch	1
(iii)	keep at correct temperature / keep temperature constant / eq;	Ignore fair test	

Question number	Answer	Notes	Marks
(c) (i)	1. volume / concentration of amylase; 2. volume / concentration of starch; 3. volume / concentration of iodine / drops of iodine; 4. volume / concentration of mixture;	Allow amount only once	2
(ii)	temperature;	Ignore time	1
(d)	1. 6 minutes / between 5 and 6 minutes / eq; 2. iodine stays yellow / orange / brown / iodine stays same colour / colourless / not blue black; 3. no starch present; 4. digested/broken down ;	Reject 6-7 mins	3
(e)(i)	1. fewer wells with blue black colour / more wells yellow / orange / brown / colourless / eq; 2. starch digested sooner / quicker / reaction completed sooner / eq;		2
(ii)	1. enzymes work faster at 40^{0}C / ref to optimum / eq; 2. more (kinetic) energy / molecules move faster / eq; 3. more collisions / more enzyme substrate complexes /eq;	Ignore ref to denature	2

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Core Practical 3: pH and enzyme activity

2.14 B Core practical: Investigate how enzyme activity can be affected by changes in pH

Links to the specification content

2.10	Understand the role of enzymes as biological catalysts in metabolic reactions
2.11	Understand how enzyme function can be affected by changes in pH altering the active site
2.31	Understand the role of bile in neutralising stomach acid and emulsifying lipids

Introducing the practical

The enzyme chosen depends upon student familiarity with different enzymes.

The digestion of starch by amylase can be used with students using potassium iodide to detect the presence of starch. If the concentrations and volumes are appropriate, then the digestion of the starch will be not too fast or too slow. Students are looking for the time at which the digestion mixture no longer contains any starch. This experiment can then be repeated at different pH.

The pH can be altered by adding 1 cm^3 sodium carbonate solution, 0.5 cm^3 sodium carbonate solution, 2 cm^3 ethanoic (acetic) acid or 4 cm^3 ethanoic (acetic) acid. The pH of each solution can be determined by using universal indicator paper.

If the practical is done at pH 7, nothing added, then it can be repeated by different groups within a class at a range of pH's and data pooled.

Students will need to understand the relationship between time taken for digestion to be completed and rate of reaction.

It is of course possible to use other enzymes such as catalase from potato.

Further information on this experiment can be found here on the Nuffield website.

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pH and enzyme activity

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

- What is the relationship between time taken for starch to be digested and rate of reaction?
- What are the independent, dependent and control variables in the investigation?
- How can the effect of pH on enzyme action be explained?
- Why would this practical be difficult using protease enzymes?

Skills that are covered in the practical:

- Identify independent, dependent and control variables
- Selecting appropriate apparatus
- Measuring volumes of liquid accurately
- Observing and recording changes
- Producing appropriate results tables
- Ability to carry out investigation safely
- Analyse and interpret data to draw conclusions that are consistent with the evidence
- Assess the reliability of an experimental activity
- Evaluate data and methods considering factors that affect accuracy and validity

Maths skills:

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

4A Translate information between graphical and numerical form

4C Plot two variables (discrete and continuous) from experimental or other data

4D Determine the slope and intercept of a linear graph

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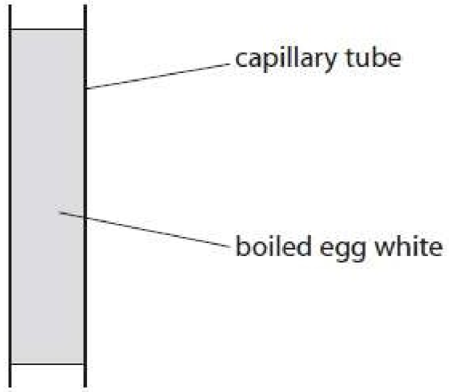
Exam Questions

A student wants to investigate the effect of secretions (juice) from the pancreas on the digestion of protein.

The white of an egg is put into fifteen 50 mm long capillary tubes. The tubes are placed in boiling water for 10 minutes until the egg white becomes solid. The diagram shows one of the tubes filled with solid egg white.



The fifteen tubes are put into three groups of five.

- five tubes are placed in a beaker of distilled water
- five tubes are placed into a beaker of juice from the pancreas
- five tubes are placed into a beaker of juice from the pancreas that has been boiled

After three hours, the length of the boiled egg white in each tube is measured in mm. The results are shown in the table.

Length of boiled egg white after three hours in mm		
Distilled water	Juice from the pancreas	Boiled juice from the pancreas
50	14	50
50	12	50
50	13	50
50	14	50
50	14	50

(a)(i) Give the dependent variable in this experiment. **(1)**

____

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(ii) Give two reasons why the results obtained by the student are reliable. **(2)**

1. ____

____

2. ____

____

(iii) Suggest how the student can obtain precise measurements of length. **(1)**

____

____

(b) (i) Explain the difference in the results obtained in distilled water compared to juice from the pancreas. (2)

____

____

____

____

(ii) Explain the difference in the results obtained in pancreas juice compared to boiled juice from the pancreas. **(2)**

____

____

____

____

(c) Suggest how you could modify this investigation to find out the effect of pH on protein digestion by pancreas juice. **(2)**

____

____

____

____

(Total for question = 10 marks)

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Mark scheme

Question number		Answer	Notes	Marks
(a)	(i)	length of egg white;		1
	(ii)	1. repeated / five tubes used / eq; 2. similar pattern / no anomalies / small range / eq;		2
	(iii)	ruler / scale / eq;	must state apparatus	1
(b)	(i)	1. no enzyme / no protease / no named protease; 2. no digestion / no break down;	ignore no change in length allow converse	2
	(ii)	1. enzyme denatured / changed active site / enzyme destroyed; 2. high temperature / heat / eq;	2. ignore boiled	2
(c)		1. acid and alkali / range of pH / different pHs / change pH; 2. no boiling of pancreas juice; 3. same volume of juice/enzyme / same concentration of juice/enzyme;	3. ignore amount	2

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Core practical 4: Diffusion and osmosis

2.17 Core practical: Investigate diffusion and osmosis using living and non-living systems

Links to the specification content

2.15	Understand the processes of diffusion, osmosis and active transport by which substances move into and out of cells
2.16	Understand how factors affect the rate of movement of substances into and out of cells, including the effects of surface area to volume ratio, distance, temperature and concentration gradient

Introducing the practical

Students should investigate the relationship between temperature, surface area and concentration gradient and the rate of diffusion in non-living systems.

Cubes of agar can be used with $KMnO_4$ or with food colouring as the diffusing substance to explore the relationship between size, volume, surface area and rate of diffusion.

Agar plates with wells cut in them can be used to look at the effect of concentration and temperature on the rate of diffusion of a food colouring.

They can also look at changes in the mass and volume of potato tissue as it is immersed in solutions of various concentrations. They can extend this investigation to determine the water potential of the potato tissue.

They should also carry out a range of investigations using onion cells to look at osmosis, plasmolysis and turgor in plant cells viewed down a microscope.

Visking tubing can also be used to look at osmosis and to demonstrate turgor and flaccidity.

Further examples of these experiments can be found here and here on the Nuffield website.

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Diffusion and osmosis

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

- How does diffusion differ from osmosis?
- How can we explain the effect of temperature, concentration and surface area on the rate of diffusion?
- How does an understanding of the relationship between size, surface area and volume help explain the need for circulation systems?
- What are the independent, dependent and control variables in the investigation?
- How can the importance of osmosis be explained in plant transport and turgor?
- How might isolated animal cells be affected by immersion in pure water or concentrated sodium chloride solution?
- How can Visking tubing be used as a model for digestion and absorption?
- How might the relationship between active transport and concentration or temperature be different from that between diffusion and concentration or temperature?

Skills that are covered in the practical:

- Identify independent, dependent and control variables
- Use of microscopes to observe plant cells and animal cells
- Selecting appropriate apparatus
- Measuring volumes of liquid accurately
- Measuring masses (of potato) accurately
- Observing and recording changes
- Producing appropriate results tables
- Ability to carry out investigation safely
- Analyse and interpret data to draw conclusions that are consistent with the evidence
- Assess the reliability of an experimental activity
- Evaluate data and methods considering factors that affect accuracy and validity

Maths skills:

1C Use ratios, fractions, percentages, powers and roots

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

4A Translate information between graphical and numerical form

4C Plot two variables (discrete and continuous) from experimental or other data

4D Determine the slope and intercept of a linear graph

5C Calculate areas of triangles and rectangles, surface areas and volumes of cubes

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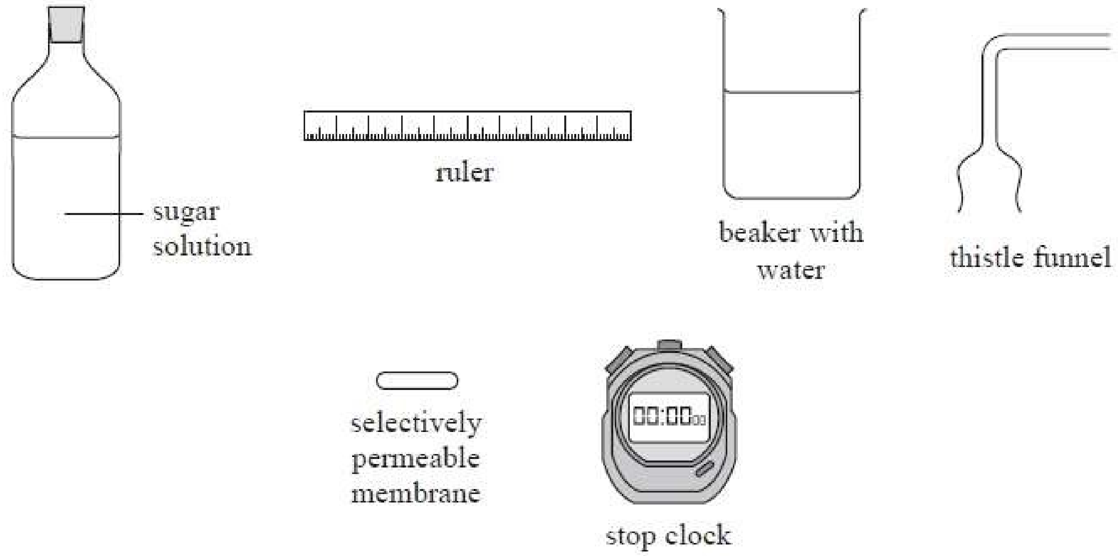
Exam Questions

(b) The diagram shows some of the apparatus used to investigate the rate of osmosis.



In the space below, draw a labelled diagram to show how you would put this apparatus together to investigate the rate of osmosis. **(4)**

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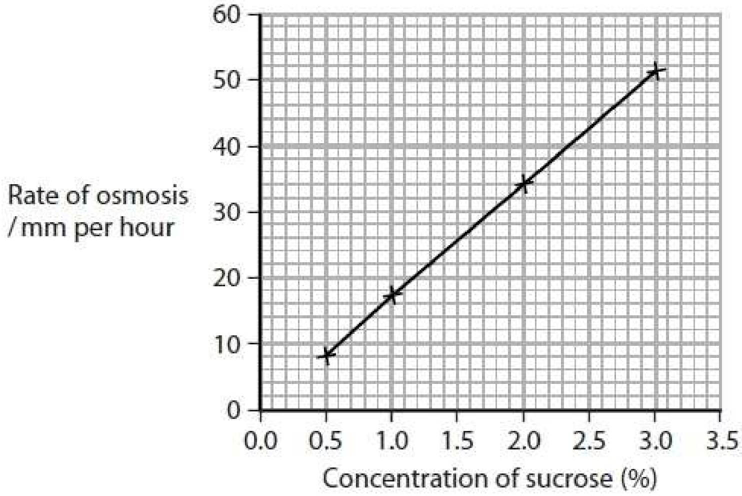
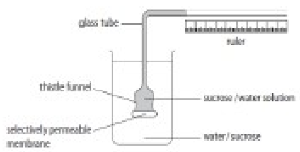
(c) The apparatus is used to find out the effect of different sucrose concentrations on the rate of osmosis.
The graph below shows the results.



Calculate, using information from the graph, the rate of osmosis in mm per minute that would occur for a sucrose concentration of 2.5%. Show your working. **(2)**

rate of osmosis = ____ mm per minute

Mark scheme

Question number	Answer	Additional guidance	Mark
(b)	An answer that makes reference to the following four points: • beaker containing water/sucrose/thistle funnel containing sucrose/water (1) • selectively permeable membrane separating sucrose from water (1) • ruler by tube of thistle funnel (1) • level of liquid shown in the tube (1)		4

Question number	Answer	Additional guidance	Mark
(c)	Identification • 42 (1) Division • 42 ÷ 60 = 0.70 (1)	award full marks for correct numerical answer without working	2

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Core Practical 5: Photosynthesis

2.23 Core practical: Investigate photosynthesis, showing the evolution of oxygen from a water plant, the production of starch and the requirements of light, carbon dioxide and chlorophyll

Links to the specification content

2.18	Understand the process of photosynthesis and its importance in the conversion of light energy to chemical energy
2.19	Know the word equation and the balanced chemical symbol equation for photosynthesis
2.20	Understand how varying carbon dioxide concentration, light intensity and temperature affect the rate of photosynthesis
2.21	Describe the structure of the leaf and explain how it is adapted for photosynthesis
2.22	Understand that plants require mineral ions for growth, and that magnesium ions are needed for chlorophyll and nitrate ions are needed for amino acids

Introducing the practical

To explore the effect of light intensity on rate of photosynthesis students can use Elodea or Myriophyllum scabratum (note – do not use other Myriophyllum species, as these can be invasive). This is a fast-growing aquarium plant, which appreciates bright light and an aquarium tank at room temperature. Both work well in releasing sufficient oxygen to count bubbles or, if time allows, collect the gas in an inverted measuring cylinder and measure the volume of oxygen evolved per unit time.

A small sprig of the pondweed can be put in a boiling tube of pond water and this can then be placed in a beaker, with a thermometer, to act as water bath. The bubbles of oxygen coming out of the freshly cut sprig can easily be counted.

The distance of a bench lamp can be moved to vary the light intensity.

The other experiments investigate the effect of no light, no carbon dioxide and no chlorophyll on photosynthesis.

These are all based on the same procedure of testing leaves for starch using potassium iodide on a leaf that has had its chlorophyll removed by boiling in ethanol. The leaves need to be destarched by placing in the dark for 24 hours so that they are free from starch at the start of the experiment.

In the case of showing light is required, one leaf is covered with foil or a stencil is used so that only the illuminated leaf produces starch.

To show chlorophyll is required, a variegated leaf, in which some of the leaf lacks chlorophyll, is used and starch is only produced in the areas that were green.

To show carbon dioxide is required one leaf of a plant is enclosed in a conical flask containing soda lime to absorb the carbon dioxide and this leaf is compared to another enclosed in a flask but without the soda lime. Only the leaf that had access to carbon dioxide produces starch.

Further information on this experiment can be found here and more information on the technique can be found here.

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Photosynthesis

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

- Why is collecting gas a more appropriate method that counting bubbles?
- Why might the volume of gas collected not be a valid measure of the rate of photosynthesis?
- What is the function of the water bath?
- What other factors might limit the rate of photosynthesis?
- Why do we need to destarch a plant before we commence our experiment?
- Why do we immerse the leaf in boiling water for a few seconds before we remove the ethanol?
- What precautions do we need to take to safely remove the chlorophyll from the leaf?
- What other methods could we use to demonstrate that photosynthesis has occurred?

Skills that are covered in the practical:

- Identify independent, dependent and control variables
- Selecting appropriate apparatus
- Measuring volumes of liquid accurately
- Measuring volumes of gas accurately
- Observing and recording changes
- Producing appropriate results tables
- Ability to carry out investigation safely
- Analyse and interpret data to draw conclusions that are consistent with the evidence
- Assess the reliability of an experimental activity
- Evaluate data and methods considering factors that affect accuracy and validity

Maths skills:

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

4A Translate information between graphical and numerical form

4C Plot two variables (discrete and continuous) from experimental or other data

4D Determine the slope and intercept of a linear graph

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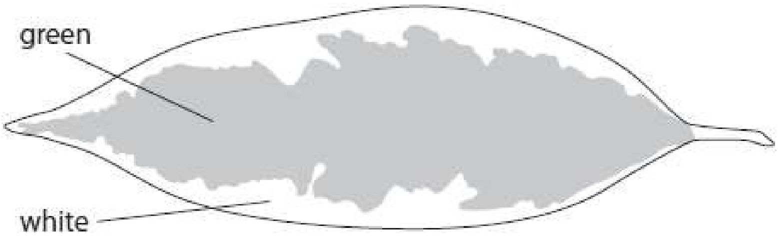
Exam Questions

(b) A student carries out an experiment to investigate the need for chlorophyll in photosynthesis.
He uses a variegated leaf as shown.



The green part of the leaf has cells that contain chlorophyll. The white part of the leaf has cells that do not contain chlorophyll.

(i) Describe the procedure used to test this leaf for starch. **(4)**

(ii) Draw a labelled diagram of the leaf to show its appearance after the student has completed the test for starch. **(2)**

(c) Suggest a method the student could use to measure the area of the green part of the leaf. **(2)**

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Mark scheme

Question number	Answer	Mark
(b)(i)	A description that makes reference to four of the following points: • place leaf in boiling water (1) • place leaf in boiling ethanol (1) • use water bath/safe heating/no naked flame (1) • place leaf in water (1) • place leaf in iodine solution (1) • blue/black indicates starch; orange/yellow indicates no starch (1)	**4**

Question number	Answer	Additional guidance	Mark
(b)(ii)	A drawing showing the following: • white part labelled orange/yellow/no starch (1) • green part labelled blue/black/starch (1)	allow approximate shape	**2**

Question number	Answer	Mark
(c)	A method that includes two of the following points: • trace around the leaf/use transparent paper/equivalent (1) • trace around the green part (1) • put onto squared paper (1) • count the number of squares (1) • reference to both sides of leaf being measured (1)	**2**

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Core practical 6: Food energy content

2.33 B Core practical: Investigate the energy content in a food sample

Links to the specification content

2.24	Understand that a balanced diet should include appropriate proportions of carbohydrate, protein, lipid, vitamins, minerals, water and dietary fibre
2.25	Identify the sources and describe the functions of carbohydrate, protein, lipid (fats and oils), vitamins A, C and D, the mineral ions calcium and iron, water and dietary fibre as components of the diet
2.26	Understand how energy requirements vary with activity levels, age and pregnancy

Introducing the practical

To investigate the energy content of food students can burn a known mass of the food using the heat energy released to heat a known volume of water.

Suitable foods are potato crisps or puffed wheat snacks. These can be obtained as low fat or reduced fat versions, and these can be compared to the normal versions. The foodstuff is lit over a Bunsen then transferred under a boiling tube of water and the temperature change of the water is recorded. If the food stops burning, it needs to be relit until it will no longer burn.

It is also informative to calculate the energy released from the food and compare this to the values given on the packets.

Nuts should not be used as some students may have allergies.

Further information on this experiment can be found here on the Nuffield website.

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Food energy content

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

- Why is the energy value we calculate much less than the value on the packet?
- Why do individual student results show variation?
- How can we improve our method to obtain the most accurate and valid measurement we can using this apparatus?
- How could we improve our apparatus to deliver an energy value nearer to the published value?
- How does the energy value relate to the nutritional information on the food packet?

Skills that are covered in the practical:

- Identify independent, dependent and control variables
- Selecting appropriate apparatus
- Measuring volumes of liquid accurately
- Measuring temperature change accurately
- Observing and recording changes
- Producing appropriate results tables
- Ability to carry out investigation safely
- Analyse and interpret data to draw conclusions that are consistent with the evidence
- Assess the reliability of an experimental activity
- Evaluate data and methods considering factors that affect accuracy and validity

Maths skills:

1D Make estimates of the results of simple calculations, without using a calculator

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

2C Construct and interpret bar charts

3C Substitute numerical values into algebraic equations using appropriate units for physical quantities

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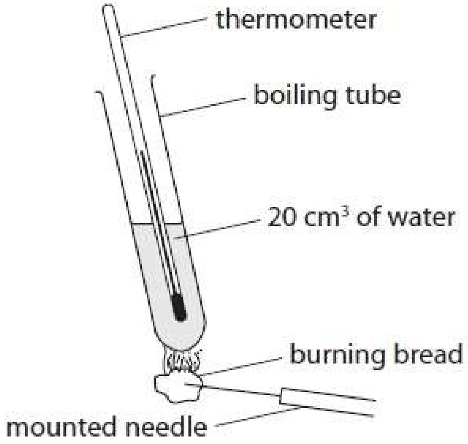
Exam question

This apparatus can be used to determine the energy value of food such as dried bread.



(a) John suggested that a more accurate value could be obtained if a larger volume of water was used.

Explain why John's suggestion might be correct. **(2)**

(b) Suggest **one** other modification and explain how it would improve the accuracy of the result. **(2)**

(Total for question = 4 marks)

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Mark scheme

Question number	Answer	Notes	Marks
(a)	smaller surface area to volume ratio; less heat loss / more energy measured / eq; heats up slowly / avoid boiling / eq;	accept converse	2
(b)	insulation / lid / cover / eq; less heat/energy loss; burning food close to tube / eq; less heat/energy loss; quick transfer of burning food / eq; less heat/energy loss; stir / eq; even temperature; avoid draft / wind; less heat/energy loss; digital thermometer ; precision / eq; use calorimeter / burn in oxygen; all food burnt / less heat/energy loss;	mark in discrete pairs reject idea of more bread ignore repeat	2
		Total	**4**

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Core practical 7: Respiration

2.39 Core practical: Investigate the evolution of carbon dioxide and heat from respiring seeds or other suitable living organisms

Links to the specification content

2.34	Understand how the process of respiration produces ATP in living organisms
2.35	Know that ATP provides energy for cells
2.36	Describe the differences between aerobic and anaerobic respiration
2.37	Know the word equation and the balanced chemical symbol equation for aerobic respiration in living organisms
2.38	Know the word equation for anaerobic respiration in plants and in animals

Introducing the practical

Respiring seeds can be placed in a thermos or vacuum flask and be shown to produce an increase in temperature in the flask if left for two or three days. Germinating wheat works well. You can use boiled seeds as a control and should use bleach or hypochlorite solution to sterilise the seeds and prevent microbial respiration from causing an increase in temperature.

Respiring seeds or blowfly larvae can be used to show that carbon dioxide is released during respiration. The gas released can be bubbled through limewater, which turns cloudy, or through sodium hydrogen-carbonate indicator, which turns from orange to yellow.

Further information on this experiment can be found here on the Nuffield website.

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Respiration

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

- Why is it important to sterilise the boiled seeds?
- Can we tell if the respiration is aerobic or anaerobic?
- What is the advantage of using limewater rather than another indicator?
- How could we make the investigation into respiration quantitative?
- How else could we show respiration is taking place other than by energy release or carbon dioxide production?

Skills that are covered in the practical:

- Identify independent, dependent and control variables
- Selecting appropriate apparatus
- Measuring volumes of liquid accurately
- Measuring temperature change accurately
- Observing and recording changes
- Producing appropriate results tables
- Ability to carry out investigation safely
- Analyse and interpret data to draw conclusions that are consistent with the evidence

Maths skills:

2B Understand and find the arithmetic mean (average)

2C Construct and interpret bar charts

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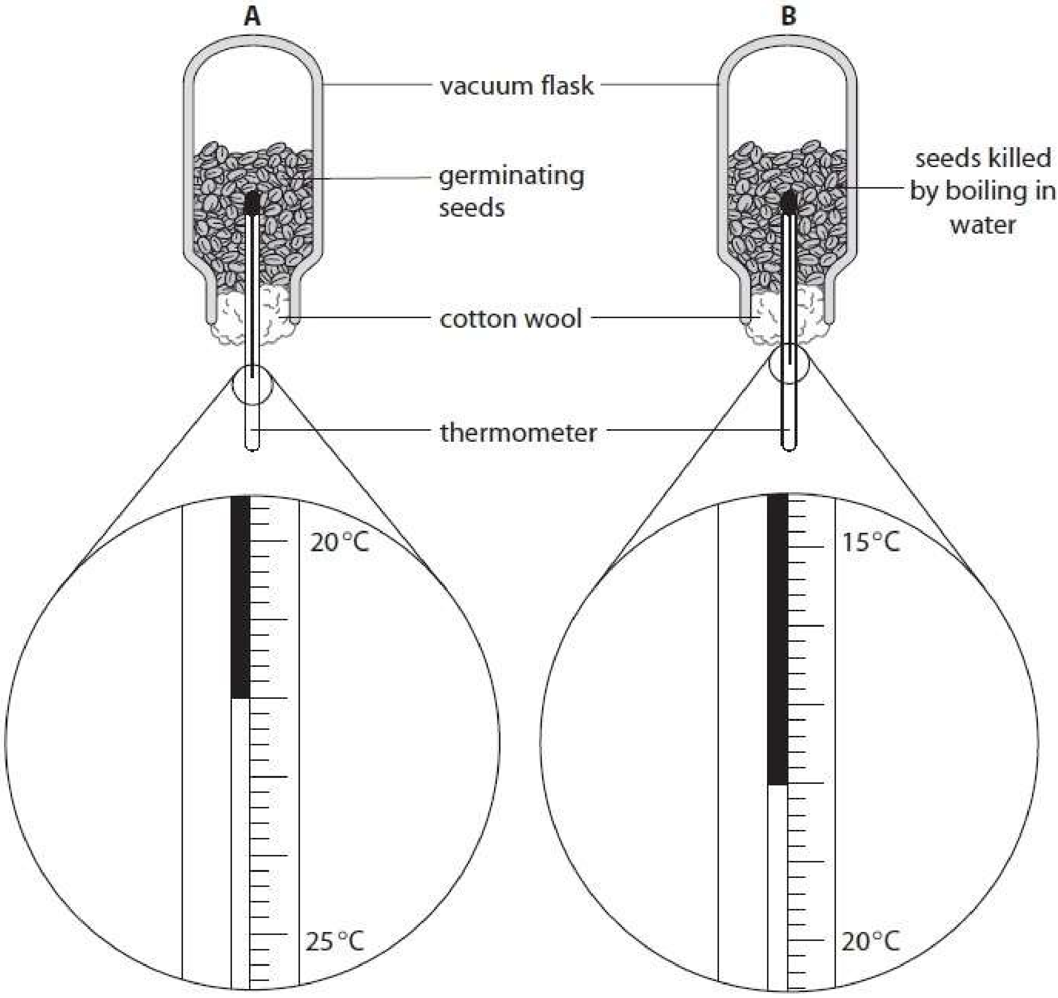
Exam questions

The diagram shows the apparatus used in a seed germination experiment.



(a) The two samples of seeds started at the same temperature of 18°C.
The diagram shows the temperature reading on each thermometer after 48 hours.

(i) Complete the table to show the temperature of flask A and flask B. (1)

Temperature in °C	
Flask A	Flask B

(ii) Give a biological explanation for the difference in the temperature of flask A compared to flask B. **(2)**

(b) The seeds in both flasks were washed in disinfectant before being put into the flasks. Suggest why this was done. **(1)**

(c) The cotton wool kept the thermometers in place and prevented the seeds from falling out of the flasks.

Suggest why cotton wool was used rather than a rubber bung. **(1)**

(d) The seeds used in the experiment were from the same species.

Suggest **one** other variable that needs to be controlled in this experiment. **(1)**

(Total for question = 6 marks)

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Mark scheme

Question number	Answer	Notes	Marks
(a) (i)	flask A 22 and flask B 18 (both temperatures correct) ;	units not required	1
(ii)	respiration; heat released / eq;	allow converse ignore energy / warmth	2
(b)	kill bacteria / kill microorganisms / remove bacteria / no bacteria / fewer bacteria / sterilise / eq;	ignore other organisms	1
(c)	oxygen (in) / carbon dioxide (out);	ignore air / gas / gas exchange; reject oxygen out alone / carbon dioxide in alone eg to allow oxygen in and out = 1 allow movement of oxygen / carbon dioxide	1
(d)	mass / number / age / amount (of seeds) / eq;	ignore health / time / outside temperature ignore size	1
		Total	**6**

Core practical 8: Light intensity and photosynthesis

2.45 B Core practical: Investigate the effect of light on net gas exchange from a leaf, using hydrogen-carbonate indicator

Links to the specification content

2.40 B	**understand the role of diffusion in gas exchange**
2.41 B	**understand gas exchange (of carbon dioxide and oxygen) in relation to respiration and photosynthesis**
2.42 B	**understand how the structure of the leaf is adapted for gas exchange**
2.43 B	**describe the role of stomata in gas exchange**
2.44 B	**understand how respiration continues during the day and night, but that the net exchange of carbon dioxide and oxygen depends on the intensity of light**
2.18	understand the process of photosynthesis and its importance in the conversion of light energy to chemical energy
2.19	know the word equation and the balanced chemical symbol equation for photosynthesis
2.20	understand how varying carbon dioxide concentration, light intensity and temperature affect the rate of photosynthesis

Introducing the practical

This investigation uses sodium hydrogen-carbonate indicator to show the changes in carbon dioxide concentration in the air surrounding leaves in different light conditions.

Leaves of, for example, privet are placed in three of four boiling tubes containing a small volume (2 cm^3) of indicator. Students will sometimes think adding more indicator will produce a quicker change.

It is important that the indicator is in balance with the atmosphere and is red or orange in colour.

One tube is placed in bright light, one is wrapped in foil, one is wrapped in muslin and the tube without a leaf is also left in bright light. The tubes are then left for 40 minutes.

The leaf in the light changes the indicator to a purple colour, the one in darkness changes the indicator to a yellow colour and the one in dim light will remain red. The tube in light without a leaf will also remain red.

Further examples of this experiment can be found here and here.

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Light intensity and photosynthesis

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

- What is the function of the empty tube?
- Why is hydrogen-carbonate indicator used rather than limewater?
- Why is a small volume of indicator used in this experiment?
- What other factors will influence the gas exchange in the tubes?
- How do the each of the three experimental tubes represent a different time of day?
- How do changes in gas exchange reflect processes going on in the leaf cells?

Skills that are covered in the practical:

- Identify independent, dependent and control variables
- Selecting appropriate apparatus
- Measuring volumes of liquid accurately
- Observing and recording changes
- Producing appropriate results tables
- Analyse and interpret data to draw conclusions that are consistent with the evidence

Exam questions

Ian wanted to investigate how gas exchange in a flowering plant changed with light intensity.

He set up an experiment using four tubes. Each of the tubes contained orange hydrogen carbonate indicator solution and was sealed with a cork. Ian added a fresh leaf to tubes A, B and C. Tube D had no leaf.

The tubes were then left in the following conditions:

- Tube A was placed in direct sunlight.
- Tube B was covered with aluminium foil to prevent any light entering the tube.
- Tube C was covered with thin cloth that allowed some light to enter the tube.
- Tube D was also placed in direct sunlight. He left the tubes in the laboratory for one hour and then returned to look at the colour of the indicator solution in the tubes.

(a) Suggest a hypothesis for Ian's investigation. **(2)**

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(b) Give **two** variables that Ian should keep constant in his investigation. **(2)**

(c) State the purpose of Tube D in the investigation. **(1)**

(d) Ian recorded his results in a table.

Tube	Colour of indicator at start	Colour of indicator after one hour
A	orange	purple
B	orange	yellow
C	orange	orange
D	orange	orange

(i) Explain the change in colour of the indicator in Tube A. **(2)**

(ii) Explain the change in colour of the indicator in Tube B. **(2)**

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(e) Suggest why the indicator did not change colour in:

(i) Tube C **(1)**

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(ii) Tube D **(1)**

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(f) Limewater is an indicator that can be used to show an increase in the level of carbon dioxide.
Suggest why it would **not** be a suitable indicator for use in this investigation. **(1)**

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(Total for question = 12 marks)

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Mark scheme

Question number	Answer	Notes	Marks
(a)	light (intensity); affects/alters/increases/decreases/changes CO_2 level / gas exchange / photosynthesis;		2
(b)	size / species of leaves / eq; volume/amount/concentration of indicator; temperature;	ignore ref to tube size / time / cork seal / humidity	max 2
(c)	control / allow (valid) comparison / see if indicator changes (with no leaf) / colour change due to leaf / see if gas exchange happens without the leaf / eq;		1
(d) (i)	photosynthesis / allow photosynthesis more than respiration; less CO_2 / CO_2 absorbed / eq;	ignore photosynthesis and respiration unqualified ignore ref to pH	2
(ii)	respiration / <u>no</u> photosynthesis; CO_2 released / more CO_2 / no CO_2 absorbed / eq;	ignore ref pH	2
(e) (i)	respiration equals photosynthesis / CO_2 in equals CO_2 out / eq;	ignore gas exchange	1
(ii)	<u>no leaf</u>;	ignore empty tube / nothing in tube	1
(f)	limewater only shows increase in CO_2 / cannot show decrease in CO_2 / cannot show amount of CO_2 / eq;		1

TOTAL 12 MARKS

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Core practical 9: Human respiration

2.50 Core practical: Investigate breathing in humans, including the release of carbon dioxide and the effect of exercise

Links to the specification content

2.34	Understand how the process of respiration produces ATP in living organisms
2.36	Describe the differences between aerobic and anaerobic respiration
2.37	Know the word equation and the balanced chemical symbol equation for aerobic respiration in living organisms
2.38	Know the word equation for anaerobic respiration in plants and in animals
2.48	Explain how alveoli are adapted for gas exchange by diffusion between air in the lungs and blood in capillaries

Introducing the practical

This investigation uses limewater or hydrogen-carbonate indicator to compare the content of inhaled and exhaled air. This can be done using a T-tube arrangement going from a mouthpiece into two conical flasks. The inhaled and exhaled air bubbles through the indicator as the student breathes in and out.

The changes in the colour of indicators before and after breathing can be used to illustrate the difference between inhaled and exhaled air.

The second part of the investigation is to compare breathing rates before and after exercise. This would be an ideal opportunity for students to design, plan, review and carry out an investigation perhaps using the CORMS prompt to help them.

Further information on this experiment can be found here on the Nuffield website.

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Human respiration

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

- How can we tell which flask receives inhaled and which flask receives exhaled air?
- What other differences are there between inhaled and exhaled air?
- How could we show these in a practical?
- How else does breathing change following exercise?
- How could we show these changes in a practical?

Skills that are covered in the practical:

- Identify independent, dependent and control variables
- Devise and plan investigations, using scientific knowledge and understanding when selecting appropriate techniques
- Selecting appropriate apparatus
- Measuring volumes of liquid accurately
- Observing and recording changes
- Producing appropriate results tables
- Analyse and interpret data to draw conclusions that are consistent with the evidence
- Communicate the findings from experimental activities, using appropriate technical language, relevant calculations and graphs
- Assess the reliability of an experimental activity
- Evaluate data and methods considering factors that affect accuracy and validity.

Maths skills:

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average) of breathing rate of class data

2D Construct and interpret frequency tables, diagrams and histograms of class data

2G Understand the terms mode and median

4C Plot two variables (discrete and continuous) from experimental or other data

Exam questions

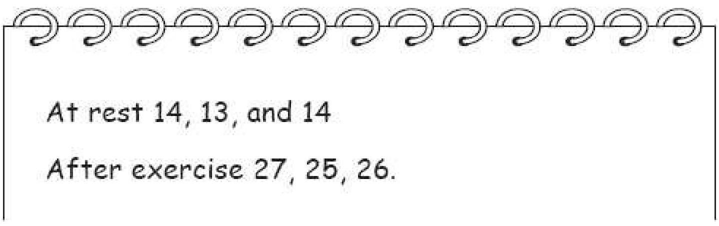
A group of students investigate the effect of exercise on breathing rate.

They measure their breathing rate at rest by counting breaths per minute.

They then exercise by running on the spot.

After exercise, they measure their breathing rate by counting breaths per minute.

These are their results.



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(a) Display these results in a table. **(2)**

(b) Explain why breathing rate is higher after exercise. **(4)**

(c) Explain how the students could improve their investigation. **(2)**

(Total for question = 8 marks)

Mark scheme

Question number	Answer	Notes	Marks
(a)	1. before and after exercise; 2. breaths per minute;	allow interchangeable rows /columns ignore breathing rate no credit for graph	2
(b)	1. muscle(s); 2. respiration; 3. oxygen required; 4. remove lactic acid; 5. oxygen debt; 6. remove carbon dioxide;		4
(c)	1. repeat / use more people / eq; 2. measure breathing rate during exercise; 3. somebody else / machine / data logger / spirometer count breaths / eq; 4. run at same speed / for same time same distance / run on treadmill / eq;		2

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Core practical 10: Transpiration

2.58 B Core practical: Investigate the role of environmental factors in determining the rate of transpiration from a leafy shoot

Links to the specification content

2.54	Describe the role of xylem in transporting water and mineral ions from the roots to other parts of the plant
2.55 B	**Understand how water is absorbed by root hair cells**
2.56 B	**Understand that transpiration is the evaporation of water from the surface of a plant**
2.57 B	**Understand how the rate of transpiration is affected by changes in humidity, wind speed, temperature and light intensity**

Introducing the practical

This investigation uses a potometer to measure the rate of water uptake and therefore deduce water loss or transpiration from a leafy shoot. A simple bubble potometer consists of a straight length of capillary tube attached to a plastic collar into which the cut end of a leafy shoot is inserted. Commercially produced potometers are not required but you could show one to the students if you have one.

The students will need help to set up the potometer ensuring that the shoot fits snugly into the collar and that there are no leaks or bubbles in the tube. A bucket filled with water that enables the potometer to be immersed vertically will help to remove unwanted bubbles.

When set up, the bottom of the capillary tube can be placed in a beaker of water. It can then be lifted out until a small air bubble appears then replaced in the beaker to 'seal' the bubble.

Once set up the students can measure the transpiration rate as distance the bubble travels in one minute. They should take several readings and calculate a mean rate.

If the students are careful, they can use the plastic collar to squeeze out the bubble from the bottom of the capillary tube when it gets too high up the capillary tube. They can then lift the tube out of the beaker and allow a new bubble to form, replace the tube in the water and carry on with their readings. This will save a lot of time, as the apparatus will not need to be dismantled.

Each potometer can be used to collect readings in normal air, windy conditions (e.g. using a hairdryer on cold), increased temperature, increased humidity (e.g. using a clear plastic bag), darkness and finally with half of the leaves removed.

Students could decide how they could vary conditions. Class data can be collected, and a discussion should ensue on how we can combine data from different shoots and potometers.

Further information on this experiment can be found here on the Nuffield website.

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Transpiration

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

- What is the best way to vary the environmental conditions around the shoot?
- What assumptions are we making about absorption rate?
- Is all the water absorbed lost?
- Why do we need to calculate % change in transpiration rate for each condition compared to normal transpiration rate?
- What is the best way to display our results in a graph?
- What extra information would a weight potometer provide us with?

Skills that are covered in the practical:

- Identify independent, dependent and control variables
- Devise and plan investigations, using scientific knowledge and understanding when selecting appropriate techniques
- Selecting appropriate apparatus
- Observing and recording changes
- Producing appropriate results tables
- Analyse and interpret data to draw conclusions that are consistent with the evidence
- Communicate the findings from experimental activities, using appropriate technical language, relevant calculations and graphs
- Assess the reliability of an experimental activity
- Evaluate data and methods considering factors that affect accuracy and validity.

Maths skills:

1C Use ratios, fractions, percentages, powers and roots

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average) of class data

2C Construct and interpret bar charts

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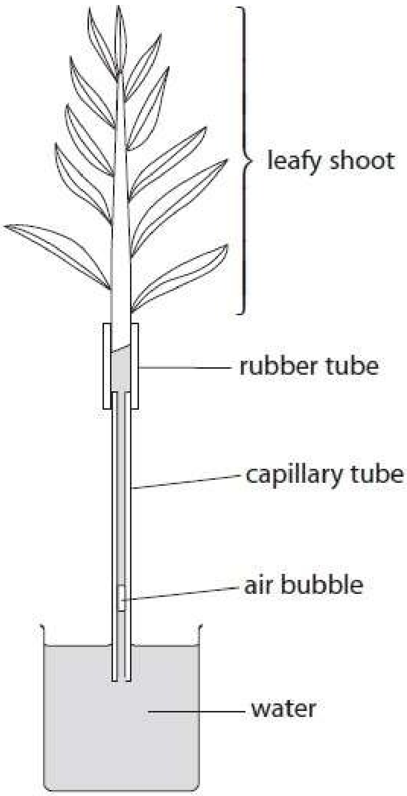
Exam questions

Steven wanted to measure the rate of water loss from a leafy shoot. He set up this apparatus in normal laboratory conditions.



(a) Name the apparatus Steven used. **(1)**

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(b) Name the process by which a plant loses water. **(1)**

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(c) Describe how Steven should set up the apparatus and how he should then use it to estimate the rate of water loss from the leafy shoot. **(4)**

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(d) Steven carried out three further experiments. He used the same plant but changed one condition in each experiment.

The table shows the percentage change in rate of water loss for each condition when compared to Steven's original experiment.

Condition	Percentage change in rate of water loss (%)
wind increased	+23
Light intensity reduced	-40
half of the leaves removed	-48

Explain the change in water loss when

(i) wind was increased. **(2)**

(ii) light intensity was reduced. **(1)**

(iii) half of the leaves were removed. **(2)**

(e) Suggest how Steven could increase the wind around the leafy shoot. **(1)**

(Total for question = 12 marks)

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Mark scheme

Question number	Answer	Notes	Marks
(a)	potometer;		1
(b)	transpiration / evaporation / diffusion;		1
(c)	1 cut under water; 2 water tight / air tight / seal / eq; 3 how bubble introduced; 4 dry leaves / eq; 5 measure distance bubble moves / length of bubble eq; 6 scale / ruler / cm / eq; 7 time / second / minute / hour / day; 8 repeat;		Max 4
(d) (i)	blows water away / removes water / eq; (maintains) diffusion gradient / conc. gradient / eq;		2
(ii)	stomata close / pores close;	ignore guard cells	1
(iii)	less surface / area; (fewer) idea of reduced number of stomata / pores;		2
(e)	fan / hairdryer / outdoors / put in a draught / put in open window / eq;		1
		Total	**12**

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Core practical 11: Seed germination

3.5 Core practical: Investigate the conditions needed for seed germination

Links to the specification content

3.4	Understand that the growth of the pollen tube followed by fertilisation leads to seed and fruit formation
3.6	Understand how germinating seeds utilise food reserves until the seedling can carry out photosynthesis

Introducing the practical

This investigation looks at the conditions needed for germination. Suitable conditions to investigate would be the temperature, availability of oxygen, and availability of water. Cress seeds work well as do peas and results can be obtained within three to four days. The different conditions can be obtained by putting one tube containing seeds in a fridge, one with boiled water and an oxygen absorber such as sodium pyrogallol and one using dry rather than moist cotton wool.

Class results can be combined and % germination calculated for each condition.

Further information on this experiment can be found here on the Nuffield website.

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Seed germination

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

- How can we tell if a seed has germinated?
- What different molecules do the seeds use as energy stores?
- Explain why each condition is required for successful germination.

Skills that are covered in the practical:

- Identify independent, dependent and control variables
- Devise and plan investigations, using scientific knowledge and understanding when selecting appropriate techniques
- Selecting appropriate apparatus
- Observing and recording changes
- Producing appropriate results tables
- Analyse and interpret data to draw conclusions that are consistent with the evidence

Maths skills:

1C Use ratios, fractions, percentages, powers and roots
2A Use an appropriate number of significant figures
2B Understand and find the arithmetic mean (average) of class data
2C Construct and interpret bar charts

Exam questions

A student wanted to investigate the conditions required for the germination of seeds.

He set up 5 boiling tubes each containing 10 cress seeds on cotton wool sealed with rubber bungs.

- Tube A contained dry cotton wool and was placed at room temperature in the light.
- Tube B contained moist cotton wool and was placed at room temperature in the light.
- Tube C contained moist cotton wool and was placed in a fridge in the dark.
- Tube D contained moist cotton wool and was placed at room temperature in the dark.
- Tube E contained moist cotton wool and was placed at room temperature in the light and contained alkaline pyrogallol to absorb oxygen.

The student left the tubes for 3 days and then returned to observe the results.

He measured the height of the seedlings and recorded how many had germinated.

Some of his results are shown below.

Tube A no seeds germinated.

Tube B 9 seeds germinated with the following heights: 2.0 cm, 2.1 cm, 3.1 cm, 2.2 cm, 2.1 cm, 1.8 cm, 2.3 cm, 2.7 cm and 2.5 cm.

Tube C one seed germinated with a height of 0.3 cm.

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(a) Complete the summary table to show the conditions and the results for tubes A, B and C only. **(4)**

Tube	Location	Water	Light	% seeds germinated	Average height in cm
A	room		yes		
B		yes			
C					0.3

(b) Explain how the student could tell whether the seeds had germinated. **(2)**

(c) The student's teacher commented that there were too many different independent variables in his experiment.
Identify the independent variables in the experiment. **(2)**

(d) Explain what the results would be for tube D. **(2)**

(e) Explain why the seeds in tube E failed to germinate. **(1)**

(Total for question = 11 marks)

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Mark scheme

<table>
<tr><th>Question number</th><th>Answer</th><th>Notes</th><th>Marks</th></tr>
<tr><td>(a)</td><td>
<table>
<tr><td>tube</td><td>temperature</td><td>water</td><td>light</td><td>% seeds germinated</td><td>average height in cm</td></tr>
<tr><td>A</td><td>(room)</td><td>no</td><td>(yes)</td><td>0</td><td>0.0</td></tr>
<tr><td>B</td><td>room</td><td>(yes)</td><td>yes</td><td>90</td><td>2.3(1);</td></tr>
<tr><td>C</td><td>fridge</td><td>yes</td><td>no;</td><td>10;;</td><td>(0.3)</td></tr>
</table>
</td><td>First three columns correct for one mark

One mark for two % germination correct

Two marks for all % germination being correct

One mark for both average height being correct</td><td>4</td></tr>
<tr><td>(b)</td><td>1. seeds split / seeds burst / sprouts / eq;

2. <u>root</u> / <u>radicle</u> seen / grows / eq;

3. <u>shoot</u> / <u>plumule</u> / <u>stem</u> seen / grows / eq;</td><td>Ignore leaf/plant emerges / increase in height / become seedlings</td><td>2</td></tr>
<tr><td>(c)</td><td>temperature;

water / moisture;

light;

oxygen;</td><td>Allow one mark for two correctly named and two marks for three correctly named

Location = 0</td><td>2</td></tr>
</table>

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Core practical 12: Fieldwork – population size

4.2 Core practical: Investigate the population size of an organism in two different areas using quadrats

Links to the specification content

4.1	Understand the terms population, community, habitat and ecosystem
4.3 B	**Understand the term biodiversity**
4.4 B	**Practical: investigate the distribution of organisms in their habitats and measure biodiversity using quadrats**
4.5	Understand how abiotic and biotic factors affect the population size and distribution of organisms

Introducing the practical

This investigation looks at the method used to compare population size of a species in two different areas. For example, it could be used to investigate the effect of trampling at a goal area on a football pitch and comparing this to an area away from the goal.

Students will need to be able to distinguish between different species but do not need to be able to name them.

There are keys available to help identify common species.

The important element of this investigation is to demonstrate how a population size can be estimated by random sampling using quadrats. The quadrats should be placed in several locations using tapes to produce coordinates and random number tables to determine where each quadrat is placed.

Students will count how many of the species are found in each quadrat. Class data can be collected and used to produce a best estimate of population size.

Further information on this experiment can be found here on the Nuffield website.

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Fieldwork – population size

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

- What is meant by a random sample?
- How many quadrats should we use in each area?
- How can we decide where to place our quadrats?
- How do we scale up our data to estimate the population size in each area?
- What biotic or abiotic factors are contributing to the difference in population size?

Skills that are covered in the practical:

- Devise and plan investigations, using scientific knowledge and understanding when selecting appropriate techniques
- Selecting appropriate apparatus
- Observing and recording changes
- Producing appropriate results tables
- Analyse and interpret data to draw conclusions that are consistent with the evidence
- Communicate the findings from experimental activities, using appropriate technical language, relevant calculations and graphs
- Assess the reliability of an experimental activity
- Evaluate data and methods considering factors that affect accuracy and validity.

Maths skills:

1C Use ratios, fractions, percentages, powers and roots

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average) of class data

2C Construct and interpret bar charts

2D Construct and interpret frequency tables, diagrams and histograms

2E Understand the principles of sampling as applied to scientific data

2G Understand the terms mode and median

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Exam question

The passage describes the study of organisms and their ecosystems.

Complete the passage by writing a suitable word in each of the spaces. **(8)**

Ecology is the study of the interaction of the organisms in an ecosystem with their ______________________________. This is made up of biotic or living factors and abiotic or non–living factors.

In an ecosystem, a group of organisms of the same species living in one place is a ____________________________________. Different groups of species living in the same place or habitat is called a ______________________________.

To study the number and distribution of plants in an area, a wooden or metal frame is used. This is called a __________________________________. To compare numbers of organisms in two areas several frames need to be placed at ____________________________ places in each area.

The numbers in each frame are combined and then divided by the total number of frames.

This is done to calculate the _______________________________ for each area. By using several frames we improve the ______________________________ of the data and make it easier to detect any ______________________________ results.

(Total for question = 8 marks)

Mark scheme

Question number	Answer	Notes	Marks
	environment; population; community; quadrat; random / different; average / mean; reliability; anomalous / unusual / odd ;		8

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Core practical 13: Fieldwork – population distribution

4.4 B Core practical: Investigate the distribution of organisms in their habitats and measure biodiversity using quadrats

Links to the specification content

4.1	Understand the terms population, community, habitat and ecosystem
4.2	*Practical: investigate the population size of an organism in two different areas using quadrats*
4.3 B	**Understand the term biodiversity**
4.5	Understand how abiotic and biotic factors affect the population size and distribution of organisms

Introducing the practical

This investigation extends the last practical (Core practical 12) to look at how biotic and abiotic factors affect the distribution of organisms in their habitats.

This requires students to measure abiotic factors, such as light intensity and link this to changes in distribution of species and changes in biodiversity.

Students will need to be able to distinguish between different species but do not need to be able to name them.

There are keys available to help identify common species.

The quadrats should be placed in several locations within each area using tapes to produce coordinates and random number tables to determine where each quadrat is placed.

Students will count how many of each species are found in each quadrat. Class data can be collected and combined to produce measures of the number of different and how many of each species present in each location.

Different measures of biodiversity can be discussed.

Further information on this experiment can be found here on the Nuffield website.

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Fieldwork – population distribution

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

- What is meant by a random sample?
- How many quadrats should we use in each area?
- How can we decide where to place our quadrats?
- How do we scale up our data to estimate the population size in each area?
- What is meant by biodiversity and how can we best measure it?
- How do we scale up our data to estimate the biodiversity in each area?
- What are the biotic or abiotic factors in each habitat?
- How can we measure these factors?
- How can we decide which are contributing to the difference in biodiversity?
- What are the problems of generalising from our data to other habitats?

Skills that are covered in the practical:

- Devise and plan investigations, using scientific knowledge and understanding when selecting appropriate techniques
- Selecting appropriate apparatus
- Observing and recording changes
- Producing appropriate results tables
- Analyse and interpret data to draw conclusions that are consistent with the evidence
- Communicate the findings from experimental activities, using appropriate technical language, relevant calculations and graphs
- Assess the reliability of an experimental activity
- Evaluate data and methods considering factors that affect accuracy and validity.

Maths skills:

1C Use ratios, fractions, percentages, powers and roots

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average) of class data

2C Construct and interpret bar charts

2D Construct and interpret frequency tables, diagrams and histograms

2E Understand the principles of sampling as applied to scientific data

2G Understand the terms mode and median

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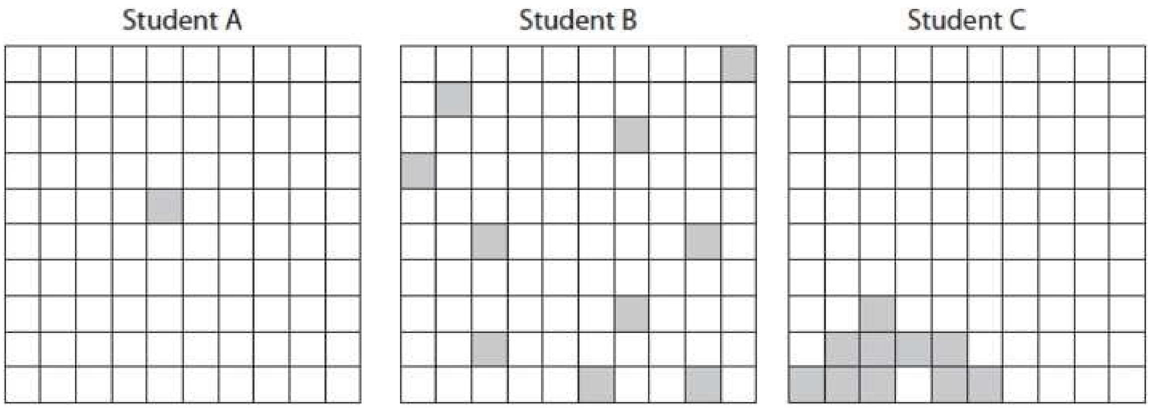
Exam question

Three students were asked to estimate the population size of a plant species in an area by using a quadrat.

The diagram shows where each student placed their quadrat in the area.



(a) (i) Which student would obtain the most reliable estimate?
Give reasons for your answer. **(2)**

____

____

____

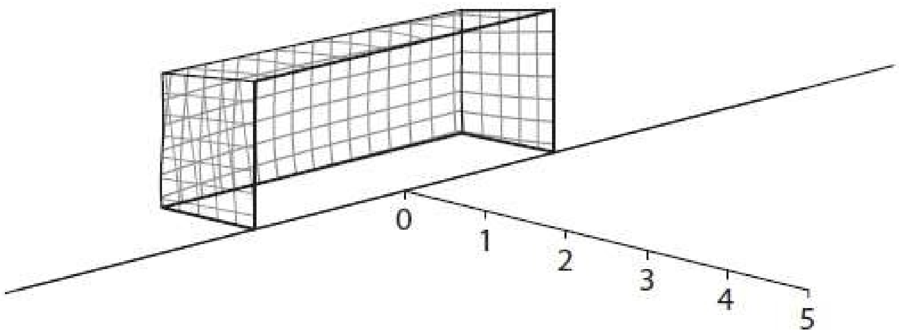
____

(ii) State what is meant by the term population. **(1)**

____

____

(b) Five other students investigated the distribution of grass in the goal area of a football pitch.
They placed a small quadrat at the goal line and then at one metre intervals in a straight line away from the goal line. The diagram shows their method.



The quadrat was 10 cm by 10 cm and was made from clear plastic. It was marked into 100 squares of 1 cm × 1 cm. If grass could be seen in 10 of the squares, the percentage cover would get a score of 10%.

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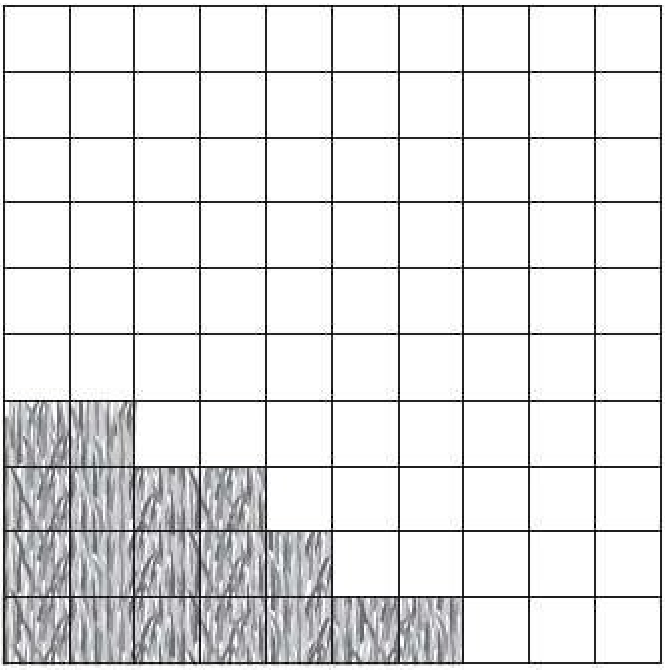
The table shows the results obtained by the five students.

Student	Percentage cover of grass at different distances from the goal line					
	0 m	1 m	2 m	3 m	4 m	5 m
A	14	14	38	41	90	100
B	20	13	5	47	82	90
C	15	14	45	50	86	85
D	10	18	35	50	75	83
E	10	15	30	50	70	90
average	14	15	37	48	81	90

(i) One of the averages of the results has been calculated ignoring an anomalous result.
Which student obtained the anomalous result? **(1)**

____

(ii) The diagram shows a quadrat used by one of the students, and the number of 1cm squares where grass can be seen.



Which student obtained the results shown in this quadrat? **(1)**

____

(Total for question = 5 marks)

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Mark scheme

Question number		Answer	Notes	Marks
(a)	(i)	(student B) 1. random / spread out / scattered / eq; 2. used 10 quadrats / repeated use of quadrats / several / eq;		2 max
	(ii)	number / all / total / amount of named species / of a species / of one species;	number of species = 0 number of organisms = 0 number of same organism = 1 number of an organism = 1 Ignore group	1
(b)	(i)	(student) B;		1
	(ii)	(student) D;		1

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Core practical 14: Anaerobic respiration

5.6 Core practical: Investigate the role of anaerobic respiration by yeast in different conditions

Links to the specification content

1.2	Fungi: these are organisms that are not able to carry out photosynthesis; their body is usually organised into a mycelium made from thread-like structures called hyphae, which contain many nuclei; some examples are single-celled; their cells have walls made of chitin; they feed by extracellular secretion of digestive enzymes onto food material and absorption of the organic products; this is known as saprotrophic nutrition; they may store carbohydrate as glycogen. Examples include *Mucor*, which has the typical fungal hyphal structure, and yeast, which is single-celled
2.36	Describe the differences between aerobic and anaerobic respiration
2.38	Know the word equation for anaerobic respiration in plants and in animals
2.39	Practical: investigate the evolution of carbon dioxide and heat from respiring seeds or other suitable living organisms
5.5	Understand the role of yeast in the production of food including bread

Introducing the practical

This investigation gives students the chance to experiment on the factors that affect respiration in yeast.

The basic experiment uses a mixture of yeast and glucose in a boiling tube with paraffin oil on the surface to prevent entry of air containing oxygen. Diazine green can be added to the mixture. This indicator is blue in the presence of oxygen but turns pink in the absence of oxygen. So initially, the yeast respires aerobically until it has used up all the oxygen. From this point, the yeast cells respire anaerobically.

The rate of respiration can be measured either by collecting the carbon dioxide given off by downward displacement using a water filled measuring cylinder or by counting the bubbles. Students can discuss the advantages and disadvantages of each method.

Using limewater or hydrogen-carbonate indicator, the gas given off can be shown to be carbon dioxide.

The investigation can have several alternative independent variables such as temperature, concentration of glucose or even using different sugars as a substrate.

As with other investigations this could be used as an opportunity for students to design, plan, review and carry out an investigation perhaps using the CORMS prompt to help them.

Further information on this experiment can be found here.

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Anaerobic respiration

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

- Why is collecting gas a more appropriate method that counting bubbles?
- Why might the volume of gas collected not be a valid measure of the rate of respiration?
- What is the function of the water bath?
- What other affects might increasing the temperature have on the volume of gas produced?
- What other factors might affect the rate of respiration?
- What other methods could we use to demonstrate that respiration is occurring?
- Why might different sugars produce different rates of anaerobic respiration?

Skills that are covered in the practical:

- Identify independent, dependent and control variables
- Selecting appropriate apparatus
- Measuring volumes of liquid accurately
- Measuring volumes of gas accurately
- Observing and recording changes
- Producing appropriate results tables
- Ability to carry out investigation safely
- Analyse and interpret data to draw conclusions that are consistent with the evidence
- Assess the reliability of an experimental activity
- Evaluate data and methods considering factors that affect accuracy and validity

Maths skills:

2A Use an appropriate number of significant figures

2B Understand and find the arithmetic mean (average)

4A Translate information between graphical and numerical form

4C Plot two variables (discrete and continuous) from experimental or other data

4D Determine the slope and intercept of a linear graph

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Exam Question

Describe an experiment you could do to find out the effect of pH on the growth of yeast. **(6)**

(Total for question = 6 marks)

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Mark scheme

Question number	Answer		Marks
	C O R M1 dioxide / M2 S1 and S2	vary pH / acid + alkali / eq; same species / mass / number / concentration / amount of yeast / eq; repeat each pH / eq; mass / number / bubbles / carbon alcohol / eq; time period stated; same temp / volume of water / same nutrients / conc. of nutrients / oxygen / eq;; Ignore light	Max 6

Total 6 Marks

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Appendix 1

Department for Education: apparatus and techniques list

	BIOLOGY	CHEMISTRY	PHYSICS
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	Use of appropriate apparatus to make and record a range of measurements accurately, including mass, time, temperature, and volume of liquids and gases	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects.
2	Safe use of appropriate heating devices and techniques including use of a Bunsen burner and a water bath or electric heater	Safe use of appropriate heating devices and techniques including use of a Bunsen burner and a water bath or electric heater	Use of appropriate apparatus to measure and observe the effects of forces including the extension of springs
3	Use of appropriate apparatus and techniques for the observation and measurement of biological changes and/or processes	Use of appropriate apparatus and techniques for conducting and monitoring chemical reactions, including appropriate reagents and/or techniques for the measurement of pH in different situations	Use of appropriate apparatus and techniques for measuring motion, including determination of speed and rate of change of speed (acceleration/deceleration)
4	Safe and ethical use of living organisms (plants or animals) to measure physiological functions and responses to the environment	Safe use of a range of equipment to purify and/or separate chemical mixtures including evaporation, filtration, crystallisation, chromatography and distillation	Making observations of waves in fluids and solids to identify the suitability of apparatus to measure speed/frequency/wavelength. Making observations of the effects of the interaction of electromagnetic waves with matter.

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5	Measurement of rates of reaction by a variety of methods including production of gas, uptake of water and colour change of indicator	Making and recording of appropriate observations during chemical reactions including changes in temperature and the measurement of rates of reaction by a variety of methods such as production of gas and colour change	Safe use of appropriate apparatus in a range of contexts to measure energy changes/transfers and associated values such as work done
6	Application of appropriate sampling techniques to investigate the distribution and abundance of organisms in an ecosystem via direct use in the field	Safe use and careful handling of gases, liquids and solids, including careful mixing of reagents under controlled conditions, using appropriate apparatus to explore chemical changes and/or products	Use of appropriate apparatus to measure current, potential difference (voltage) and resistance, and to explore the characteristics of a variety of circuit elements
7	Use of appropriate apparatus, techniques and magnification, including microscopes, to make observations of biological specimens and produce labelled scientific drawings	Use of appropriate apparatus and techniques to draw, set up and use electrochemical cells for separation and production of elements and compounds	Use of circuit diagrams to construct and check series and parallel circuits including a variety of common circuit elements
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.	Use of appropriate qualitative reagents and techniques to analyse and identify unknown samples or products including gas tests, flame tests, precipitation reactions, and the determination of concentrations of strong acids and strong alkalis	Making observations of waves in fluids and solids to identify the suitability of apparatus to measure the effects of the interaction of waves with matter.

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Appendix 2

GCSE Sciences: Equipment list

The apparatus you choose to use will depend upon the individual circumstances and availability at each centre. A risk assessment will need to be carried out for each practical based upon individual circumstances and experience of teacher and students.

Biology

No.	Specification Reference	Equipment needed (per group)
1	*2.9 - Investigate food samples for the presence of glucose, starch, protein and fat*	Eye protection, food samples, spatula, paper towels, test tubes, racks and bungs, stirrer, iodine solution (1 g iodine in 100 cm^3 0.5 mol dm^{-3} potassium iodide solution) in dropper bottle, Benedict's solution (prepared according to CLEAPSS Recipe sheet 11 (qualitative), 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.
2	*2.12 - Investigate how enzyme activity can be affected by changes in temperature*	In amylase/starch investigation in the effect of pH, for each pH tested: test tube containing 5 cm^3 freshly made 1% starch suspension (mix 5 g soluble starch with a little cold water, pour into 500 cm^3 of boiling water and stir well, then boil until you have a clear solution), test tube containing 2 cm^3 1% amylase solution, water bath 5 cm^3 syringe or pipette, beaker of water for washing pipette, eye protection, 0.01 mol dm^{-3} iodine solution, well tray (spotting tile), stop clock/stopwatch.
3	***2.14B - Investigate how enzyme activity can be affected by changes in pH***	In amylase/starch investigation in the effect of pH, for each pH tested: test tube containing 5 cm^3 freshly made 1% starch suspension (mix 5 g soluble starch with a little cold water, pour into 500 cm^3 of boiling water and stir well, then boil until you have a clear solution), test tube containing 2 cm^3 1% amylase solution, water bath 5 cm^3 syringe buffer solution at a set pH (or pipette, beaker of water for washing pipette, eye protection, 0.01 mol dm^{-3} iodine solution, well tray (spotting tile), stop clock/stopwatch. Large baking potatoes, 1 per working group, access to balances, Beaker, 100 cm^3, or boiling tube, white tile, scalpel, ruler, cork borers to cut potatoes, or potato chipper, measuring cylinder, 50 cm^3, teat pipettes, distilled water, in wash bottle.

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4	*2.17 - Investigate diffusion and osmosis using living and non-living systems*	4 Potato strips four boiling tubes and rack (or beakers) waterproof pen, 550 g/dm^3 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 cm^3 0.1 mol/dm^3 hydrochloric acid, 100 cm^3 beaker forceps white tile knife stop clock or watch
5	*2.23 - Investigate photosynthesis, showing the evolution of oxygen from a water plant, the production of starch and the requirements of light, carbon dioxide and chlorophyll*	Ethanol (IDA) kettles of boiling water, boiling tube rack, Iodine in potassium iodide, solution in dropper bottles, beaker (at least 250 cm^3), leaves, different types, such as pelargonium (pot geranium), eye protection, forceps. Plants variegated and fully green, de-starched by keeping in the dark for 48 hours. Bell jar, covering a de-starched plant, and a beaker of soda lime, secured to a glass plate or plastic tray with Vaseline or silicone grease Beaker, 600 cm^3, metre ruler, *Elodea* or other oxygenating pond plant scissors, forceps, electric lamp, clamp stand with boss and clamp.
6	***2.33B - Investigate the energy content in a food sample***	Food samples, range of foods in small pieces (cut to approximately 1 cm square/ 0.5 cm cubed if necessary) – for example, cheese, pulses, bread, biscuits, pasta, packet snacks such as crisps and others, breakfast cereals. Nuts should not be used. Balance, accurate to ± 0.1 boiling tube, clamp stand, boss and clamp, Bunsen burner, heatproof mat, measuring cylinder, 50 cm^3 or 100 cm^3, mounted needle with wooden handle, tongs or forceps for food samples that cannot be impaled, thermometer (–10°C–110°C), eye protection.
7	*2.39 - Investigate the evolution of carbon dioxide and heat from respiring seeds or other suitable living organisms*	Germinating seeds or blowfly larvae, three to four days before the experiment, soak the wheat for 24 hours and then allow the seeds to germinate in a closed container for two to three days. 2 vacuum flasks, the best results will be obtained with small vacuum flasks. Cut strips of cotton wool about 30 cm x 5 cm. thermometers 2 per group. Dilute commercial bleaching solution with four times its volume of water. Allow 300 cm^3 for each group. *Blowfly larvae* are available in shops catering for anglers from mid-June to mid-March. Allow 10g per group. The control in this case can be an empty tube or an equivalent volume of inert material such as glass or plastic beads. Lime water. Allow 10 cm^3 per group Tubing and bungs to connect material with test tube containing limewater or Sodium hydrogen carbonate solution, eye protection.

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8	***2.45B - Investigate the effect of light on net gas exchange from a leaf, using hydrogen-carbonate indicator***	*Leaves or leaf portions* from deadnettle, iris, rose, plantain, dandelion, dock, forsythia have given satisfactory results in 30-45 minutes. Allow two leaves per group. *Hydrogen carbonate indicator*. Dissolve 0.2 thymol blue and 0.1 g cresol red powders in 20 cm^3 ethanol. Dissolve 0.84 g sodium hydrogen carbonate (analytical quality) in 900 cm^3 distilled water. Add the alcoholic solution to the hydrogen carbonate solution and make the volume up to 1 litre with distilled water. Shortly before use, dilute the appropriate amount of this solution 10 times, i.e. add 9 times its own volume of distilled water. To bring the solution into equilibrium with atmospheric air; bubble air from outside the laboratory through the diluted indicator using a filter pump or aquarium pump. After about 10 minutes, the dye should be red. Allow 10 cm^3 per group, Note that the glassware and bungs must be clean. Any trace of acid or alkali will affect the indicator. 3 test-tubes and rubber bungs, 1 bench lamp (in the absence of sunlight) test-tube rack, piece of aluminium foil, about 120 x 140 mm, graduated pipette or syringe, 5 or 10 cm^3, 3 labels or a spirit marker, forceps, eye protection.
9	*2.50 - Investigate breathing in humans, including the release of carbon dioxide and the effect of exercise*	Using 5-6 mm glass delivery tubing, cut two 20 cm and two 7 cm lengths and flame polish the cut ends. Fit these two tubes through a two-hole No.21 rubber bung so that the longer one reaches nearly to the bottom of a boiling tube (25 mm X 150 mm) when the bung is securely inserted. Cut two 10-15 cm lengths of rubber tubing, 5 mm bore and 1.5 mm wall. After use, the tubes can be sterilized in a little antiseptic and washed. The apparatus must be clean and free from any trace of acid otherwise the limewater will not go milky. Each group needs one set of tubes A and B. ***Lime water***. Shake tap water with an excess of calcium hydroxide. Allow to settle overnight and decant the clear liquid. Each group needs 20 cm^3. Before the experiment, check that the limewater is effective by blowing through a sample for 30 seconds. 2 sets of apparatus as described above, 1 graduated pipette or syringe (10 cm^3) rack for holding boiling tubes. For breathing rate stopwatch clipboard.

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10	***2.58B - Investigate the role of environmental factors in determining the rate of transpiration from a leafy shoot***	Plant material ,large sink – to assemble apparatus under water or bucket, potometer – designs vary, scalpel or scissors, clamp stand with boss and clamp, marker pen, stop clock, beaker, water, plastic ruler, paper towels, thermometer (-10 °C to 110 °C), lamp, black plastic bags, clear plastic bags, fan, Vaseline or nail varnish, graph paper.
11	*3.5 - Investigate the conditions needed for seed germination*	seeds, boiling tubes, fridge, thermometer (-10 °C to 110 °C), paraffin oil, cotton wool, sodium pyrogallate (you may choose to demonstrate this rather than let students handle the pyrogallate).
12	*4.2 - Investigate the population size of an organism in two different areas using quadrats*	quadrat (e.g. 1 metre square), long tape measure (at least 20 m) with securing pegs, clipboards, recording sheets. Species keys.
13	***4.4B - Investigate the distribution of organisms in their habitats and measure biodiversity using quadrat***	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. Species keys.
14	*5.6 - Investigate the role of anaerobic respiration by yeast in different conditions*	dried yeast 1 g, dried yeast heated to 100 °C 1 g, 5% glucose solution made with boiled water 20 cm^3, limewater 15 cm^3 or sodium hydrogen carbonate solution. Paraffin oil. Diazine green if available. Boiling tube with bung and delivery tube, beaker as water bath, thermometer, eye protection.

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