

## **AS and A Level**

**Practical skills handbook**

# **BIOLOGY A BIOLOGY B (ADVANCING BIOLOGY)**

**H020/H420**

**H022/H422**

For first teaching in 2015

## **OCR Advanced Subsidiary and Advanced GCE in Biology**

Version 2.0



# Contents

## Version 2.0 – January 2024

### Version 1.4

One change of note made between Version 1.3 and Version 1.4:

1. Guidance on Appendix 3: Measurements - Uncertainties

### Version 1.3

Minor changes made between Version 1.2 and Version 1.3:

1. Updating external web links within the Resources section

### Version 1.2

One change of note made between Version 1.1 and Version 1.2:

1. Guidance on arrangements of visits and standardisation.

### Version 2.0 (January 2024)

Changes to wording to improve accessibility and clarity. Minor changes to the guidance for practical skills 1.2.1 (d), (e) and (f) to better support teacher assessment.

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# 1 Introduction

During their study of Biology, students are expected to acquire experience of planning, implementation, use of apparatus and techniques, analysis and evaluation. These skills will be indirectly assessed in the written examinations at both AS and A Level. In addition, certain planning and implementation skills will be directly assessed at A Level only, through the Practical Endorsement.

This Handbook offers guidance on the skills required for both assessments, clarifies the arrangements for the Practical Endorsement, and gives suggestions towards planning a practical scheme of work that will cover all requirements.

The specification is the document on which assessment is based and this Handbook is intended to elaborate on the content of the specification to clarify how practical skills are assessed and what practical experience is necessary to support an assessment. The Practical Skills Handbook should therefore be read in conjunction with the specification.

## How to use this handbook

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**Sections 2–4** of this handbook describe the assessment of practical skills in the AS and A Level qualifications. These sections elaborate on the information provided in the specification. Teachers are particularly advised to carefully read **Section 4**, which sets out the requirements for the Practical Endorsement – the direct assessment of practical skills in the A Level qualifications.

**Section 5** provides guidance on planning the practical scheme of work, bringing together the various aspects that should be taken into account. The guidance in this section is intended to be supportive rather than prescriptive.

**Section 6** gives some further guidance on the practical skills set out in specification Section 1.2, which are covered in the Practical Endorsement. This section is intended to support centres in planning how they will develop these skills and might also be useful to share with students.

**Appendices** provide reference information on various topics:

- **Appendices 1 and 2** provide information on health and safety and apparatus requirements, and may be useful to share with technicians.
- **Appendices 3–6** give additional information on skills related to recording and presenting experimental data, covering measurements, units, graphs and referencing respectively. This content could be shared with students to help them develop an appropriate level of skill.
- **Appendix 7** lists a number of useful resources, including additional resources and support provided by OCR.

## 2 Overview of practical skills requirements

### Summary of the assessment model

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The practical skills assessment model consists of a theoretical and a practical component.

- The 'theoretical' component is an **indirect** assessment of practical skills through the written examination taken at the end of the course.
- The 'practical' component is a **direct** assessment of practical skills displayed by students as they are performing practical work. This is assessed by the teacher across the whole of the course.

The indirect, written assessment is a component of both AS and A Level Biology. The direct assessment, known as the Practical Endorsement, is a component of A Level Biology only.

The skills required for the practical skills assessments are set out in Module 1 Development of practical skills in biology. Module 1 is divided into two sections:

- **Section 1.1** of the specification covers skills that are assessed indirectly in a written examination. These skills may be assessed in any of the written papers that constitute the written assessment, at both AS and A Level. Assessment of practical skills forms a minimum of 15% of the written assessment at both AS and A Level.
- **Section 1.2** of the specification covers skills that are assessed directly through the Practical Endorsement. Student performance is teacher-assessed against the Common Practical Assessment Criteria (CPAC).

The Practical Endorsement is a component of the assessment at A Level only. There is no direct assessment of practical skills at AS Level.

Performance in the Practical Endorsement is reported separately to the performance in the A Level as measured through the externally assessed components.

## Summary of the practical skills required

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### Skills assessed in the written examinations

The skills assessed in the written examination cover the following areas:

- Planning
- Implementing
- Analysis
- Evaluation

Questions assessing these practical skills will be embedded in contexts relating to the content of the specification.

### Skills assessed through the Practical Endorsement

The skills assessed through the Practical Endorsement cover the areas of Planning and Implementing, specifically the following:

- Independent thinking
- Use and application of scientific methods and practices
- Research and referencing
- Instruments and equipment

Students must exemplify their skill in these areas through use of the apparatus and techniques listed in the specification, Section 1.2.2.

Centres can assess a wide range of practical activities for the Practical Endorsement, which may include our suggested practicals, centre developed practicals or practicals from other publishers as long as these are appropriately mapped to the CPAC.

## AS Level students and the Practical Endorsement

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There is no direct assessment of practical skills within the AS Level qualification. However, AS Level students will benefit from completing the type of practical activities recommended within the Practical Endorsement, as well as others, for the following reasons:

- completing practical activities will help to develop the practical skills that are assessed in the written examination
- completing practical activities will support understanding of the content of the specification
- students who decide to continue to take the A Level qualification after completing AS Level will be able to use their performance on Practical Endorsement activities completed in their first year towards the Practical Endorsement, as long as appropriate records have been kept.

## 3 Practical skills assessed in a written examination

### Planning

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Specification Section 1.1.1.

*Learners should be able to demonstrate and apply their knowledge and understanding of:*

- experimental design, including to solve problems set in a practical context
- identification of variables that must be controlled, where appropriate
- evaluation that an experimental method is appropriate to meet the expected outcomes.

Experimental design should include selection of suitable apparatus, equipment and techniques for the proposed experiment.

Students will benefit from having been given the opportunity to design simple experiments, and receiving feedback on their plans. Additionally, they should routinely be asked to consider why experiments are performed in the way they are, and how the experimental set-up contributes to being able to achieve the expected outcome. Students could be asked what might be the effect of changing aspects of the method.

### Implementing

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Specification Section 1.1.2.

*Learners should be able to demonstrate and apply their knowledge and understanding of:*

- how to use a wide range of practical apparatus and techniques correctly
- appropriate units for measurements
- presenting observations and data in an appropriate format.

The practical apparatus and techniques that may be assessed are those outlined in the specification statements related to practical techniques and procedures.

Students will be expected to understand the units used for measurements taken using common laboratory apparatus. See Appendix 4 for units commonly used in practical work in biology.

Appropriate presentation of data includes use of correct units and correct number of decimal places for quantitative data. This skill also includes appropriate use of tables and graphs for presentation of data.

Further information on recording measurements and the use of graphs is given in Appendices 3 and 5, respectively.



# Analysis

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Specification Section 1.1.3.

*Learners should be able to demonstrate and apply their knowledge and understanding of:*

- processing, analysing and interpreting qualitative and quantitative experimental results
- use of appropriate mathematical skills for analysis of quantitative data
- appropriate use of significant figures
- plotting and interpreting suitable graphs from experimental results, including:
  - (i) selection and labelling of axes with appropriate scales, quantities and units
  - (ii) measurement of gradients and intercepts.

Students will benefit from having practised these skills in a range of practical contexts. Many of the skills and techniques that form part of the Practical Endorsement will also be suitable for practising these skills.

Appendix 3 gives further information about the use of significant figures. Appendix 5 gives further information about the plotting of graphs. See also the [Mathematical Skills Handbook](#) for further guidance on the mathematical skills required in analysing experimental results, and in other areas of quantitative biology.

# Evaluation

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Specification Section 1.1.4.

*Learners should be able to demonstrate and apply their knowledge and understanding of:*

- how to evaluate results and draw conclusions
- the identification of anomalies in experimental measurements
- the limitations in experimental procedures
- precision and accuracy of measurements and data, including margins of error, percentage errors and uncertainties in apparatus
- refining experimental design by suggestion of improvements to the procedures and apparatus.

Students will benefit from having practised these skills in a range of practical contexts. As a matter of course, students should be encouraged to think carefully about the procedure they are performing and how it relates to the content of the specification; this will better place them to draw appropriate conclusions, identify anomalous and unexpected results, and identify limitations in procedures. Many activities included in the Practical Endorsement, as well as others, can be extended to allow students to consider errors and uncertainties, and suggest improvements to procedures.

Appendix 3 provides further information on precision, accuracy and errors, as well as identifying anomalous results.

# 4 Practical skills assessed in the Practical Endorsement

## Introduction to the OCR Practical Endorsement

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In order to pass the Practical Endorsement, students must demonstrate by the end of the two-year A Level course that they consistently and routinely exhibit the competencies described in the Common Practical Assessment Criteria (CPAC), listed in Section 5 of the specification. These competencies must be developed through a practical programme that encompasses the skills, apparatus and techniques listed in section 1.2 of the specification and must comprise a minimum of 12 practical activities.

In our specifications, 12 Practical Activity Groups (PAGs) are presented, which provide opportunities for demonstrating competency in all required apparatus and techniques. Additionally, all of the required skills can be developed through individually practical activities. Some of the required skills are explicitly included in the requirements for individual PAGs, while others can be developed across the full range of activities.

The PAGs have been designed so that activities can be chosen that directly support the specification content. PAG1–5 support concepts that are likely to be taught in the first year of A Level, while PAG6–9 support concepts from the second year of A Level. PAG10 and PAG11 are less scaffolded activities, designed for development of the investigative skills covered in Module 1.2.1, and can be used to bring together knowledge from across the course. Finally, PAG12 allows students to demonstrate research skills and apply investigative approaches and may link in with any content from the course or beyond.

## Planning activities to cover the Endorsement requirements

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### The Practical Activity Groups

Table 1 on the next page lists the 12 Practical Activity Groups (PAGs) with the minimum of skills and use of apparatus and techniques to be covered in each. We have designed the groups to include the types of activities that will support the requirements of the Practical Endorsement, as well as the assessment of practical skills within the written examinations.

You can use Table 1 to construct a practical scheme of work that covers all requirements. Centres are not required to stick rigidly to this table, as long as overall all the requirements are covered. For example, the skills included in PAG12 could be covered as part of an activity described for another PAG, rather than as a separate activity. That is fine, as long as at least 12 activities are completed overall.

Centres are not required to cover the skills and techniques for each PAG in a single activity. Some PAGs cover a range of skills, and centres may prefer to split these out.

The Common Practical Assessment Criteria (CPAC) can be applied to student performance across all practical work performed throughout the A Level course. It is not the intention that assessment of the Practical Endorsement should only be based on performance in 12 activities, one from each PAG. For example, if you run multiple dissection activities, you can take into account students' performance across all these activities, not just their performance in an activity selected explicitly to cover PAG2.

**Table 1** Practical activity requirements for the OCR Biology Practical Endorsement.

Practical activity group (PAG)	Techniques/skills covered (minimum)
1 Microscopy	<ul style="list-style-type: none"> <li>• use of a light microscope at high power and low power, use of a graticule<sup>1</sup>, 1.2.2 (d)</li> <li>• production of scientific drawings from observations with annotations<sup>2</sup>, 1.2.2 (e)</li> </ul>
2 Dissection	<ul style="list-style-type: none"> <li>• safe use of instruments for dissection of an animal or plant organ, 1.2.2(j)</li> <li>• use of a light microscope at high power and low power, use of a graticule<sup>1</sup>, 1.2.2 (d)</li> <li>• production of scientific drawings from observations with annotations<sup>2</sup>, 1.2.2 (e)</li> </ul>
3 Sampling techniques	<ul style="list-style-type: none"> <li>• use of sampling techniques in fieldwork, 1.2.2 (k)</li> <li>• production of scientific drawings from observations with annotations<sup>2</sup>, 1.2.2 (e)</li> </ul>
4 Rates of enzyme controlled reactions	<ul style="list-style-type: none"> <li>• use of appropriate apparatus to record a range of quantitative measurements (to include mass, time, volume, temperature, length and pH)<sup>3</sup>, 1.2.2 (a)</li> <li>• use of laboratory glassware apparatus for a variety of experimental techniques to include serial dilutions<sup>4</sup>, 1.2.2 (c)</li> <li>• use of ICT such as computer modelling, or data logger to collect data, or use of software to process data<sup>5</sup>, 1.2.2 (l)</li> </ul>
5 Colorimeter OR potometer	<ul style="list-style-type: none"> <li>• use of appropriate apparatus to record quantitative measurements, such as a colorimeter or potometer, 1.2.2 (b)</li> <li>• use of laboratory glassware apparatus for a variety of experimental techniques to include serial dilutions<sup>4</sup>, 1.2.2 (c)</li> </ul>
6 Chromatography OR electrophoresis	<ul style="list-style-type: none"> <li>• separation of biological compounds using thin layer / paper chromatography or electrophoresis, 1.2.2 (g)</li> </ul>
7 Microbiological techniques	<ul style="list-style-type: none"> <li>• use of laboratory glassware apparatus for a variety of experimental techniques to include serial dilutions<sup>4</sup>, 1.2.2 (c)</li> <li>• use of microbiological aseptic techniques, including the use of agar plates and broth, 1.2.2 (i)</li> </ul>
8 Transport in and out of cells	<ul style="list-style-type: none"> <li>• use of appropriate apparatus to record a range of quantitative measurements (to include mass, time, volume, temperature, length and pH)<sup>3</sup>, 1.2.2 (a)</li> <li>• use of laboratory glassware apparatus for a variety of experimental techniques to include serial dilutions<sup>4</sup>, 1.2.2 (c)</li> <li>• use of ICT such as computer modelling, or data logger to collect data, or use of software to process data<sup>5</sup>, 1.2.2 (l)</li> </ul>
9 Qualitative testing	<ul style="list-style-type: none"> <li>• use of laboratory glassware apparatus for a variety of experimental techniques to include serial dilutions<sup>4</sup>, 1.2.2 (c)</li> <li>• use of qualitative reagents to identify biological molecules, 1.2.2 (f)</li> </ul>
10 Investigation using a data logger OR computer modelling	<ul style="list-style-type: none"> <li>• use of ICT such as computer modelling, or data logger to collect data, or use of software to process data<sup>5</sup>, 1.2.2 (l)</li> <li>• apply investigative approaches, 1.2.1 (a)</li> </ul>
11 Investigation into the measurement of plant or animal responses	<ul style="list-style-type: none"> <li>• safe and ethical use of organisms to measure plant or animal responses and physiological functions, 1.2.2 (h)</li> <li>• apply investigative approaches, 1.2.1 (a)</li> </ul>
12 Research skills	<ul style="list-style-type: none"> <li>• apply investigative approaches, 1.2.1 (a)</li> <li>• use online and offline research skills, 1.2.1 (h)</li> <li>• correctly cite sources of information, 1.2.1 (i)</li> </ul>

<sup>1,2,3,4,5</sup> These techniques/skills may be covered in *any* of the groups indicated.

Table 1 refers to learning outcomes in Section 1.2 of the specification. These learning outcomes cover the full list of skills and techniques as stated in the DfE Subject Criteria.

Some of the learning outcomes in Section 1.2 are generic and they could be covered in many different activities. These have not been explicitly included in Table 1.

It is expected that there will be ample opportunities to develop and demonstrate the following skills across the whole practical course, regardless of the exact selection of activities:

- safely and correctly use a range of practical equipment and materials, 1.2.1(b)
- follow written instructions, 1.2.1(c)
- make and record observations/measurements, 1.2.1(d) (though note *qualitative* observations are explicitly included in PAG4 and PAG7)
- keep appropriate records of experimental activities, 1.2.1(e)
- present information and data in a scientific way, 1.2.1(f)
- use appropriate tools to process data, carry out research and report findings, 1.2.1(g)
- use a wide range of experimental and practical instruments, equipment and techniques, 1.2.1(j).

## Practical Activity Support

We do not require specific activities to be completed for the Practical Endorsement. Centres may select activities of their own, or provided by third parties, and map these against the requirements.

You can contact us at [science@ocr.org.uk](mailto:science@ocr.org.uk) if you have any queries regarding selection of activities for the Practical endorsement

## Our activities

We have produced three example activities for each PAG, comprising student sheets and teacher/technician guidance. You may use them directly, adapt them to your requirements, or merely use them as reference for the types of activity that would satisfy the criteria for each PAG and the Endorsement as a whole.

The example activities are available on Teach Cambridge.

Table 2 lists the activity titles of the OCR example activities for A Level Biology. Our [Practical Activity Support Guide](#) provides more detailed guidance on these suggested activities and how you may adapt them.

**Table 2** Our PAG activities

<b>PAG1</b>	<b>PAG7</b>
<ol style="list-style-type: none"> <li>Using a light microscope to study mitosis</li> <li>The examination and drawing of blood cells observed in blood smears</li> <li>Using a light microscope to examine lung tissue</li> </ol>	<ol style="list-style-type: none"> <li>The effect of antibiotics on bacterial growth</li> <li>Dilution plating to determine the density of microbes in liquid culture</li> <li>Transformation of bacteria with plasmid DNA encoding Green Fluorescent Protein</li> </ol>
<b>PAG2</b>	<b>PAG8</b>
<ol style="list-style-type: none"> <li>Dissection of the mammalian heart</li> <li>The dissection of a stem</li> <li>Dissection of muscle fibres from chicken wings</li> </ol>	<ol style="list-style-type: none"> <li>An investigation into the water potential of potato</li> <li>Investigating osmosis in an artificial cell</li> <li>Investigating the rate of diffusion through a membrane</li> </ol>
<b>PAG3</b>	<b>PAG9</b>
<ol style="list-style-type: none"> <li>The calculation of species diversity</li> <li>Measurement of the distribution and abundance of plants in a habitat</li> <li>Investigating a correlation between a named species and the biotic and/or abiotic factors in their environment</li> </ol>	<ol style="list-style-type: none"> <li>Qualitative testing for biological molecules – proteins</li> <li>Qualitative testing for biological molecules – lipids</li> <li>Qualitative testing for biological molecules – glucose</li> </ol>
<b>PAG4</b>	<b>PAG10</b>
<ol style="list-style-type: none"> <li>The effect of substrate concentration on the rate of an enzyme controlled reaction</li> <li>The effect of enzyme concentration on the rate of reaction</li> <li>Investigating the effect of temperature on amylase activity</li> </ol>	<ol style="list-style-type: none"> <li>Investigating DNA structure using RasMol</li> <li>Using a light sensor to measure changes in turbidity to monitor microbial growth in different sugars</li> <li>Measuring pH change during yoghurt production</li> </ol>
<b>PAG5</b>	<b>PAG11</b>
<ol style="list-style-type: none"> <li>The effect of temperature on membrane permeability</li> <li>Determining glucose concentration</li> <li>Using a potometer</li> </ol>	<ol style="list-style-type: none"> <li>Investigation into the effect of exercise on pulse rate</li> <li>Investigation into heart rate changes in <i>Daphnia</i> in response to environmental changes</li> <li>Investigation into phototropism</li> <li>Investigation into the effect of plant hormones on growth</li> </ol>
<b>PAG6</b>	<b>PAG12</b>
<ol style="list-style-type: none"> <li>Identification of the amino acids in a protein using paper chromatography</li> <li>Electrophoresis of DNA fragments for analysis</li> <li>Investigation using thin layer chromatography to separate photosynthetic pigments</li> </ol>	<ol style="list-style-type: none"> <li>Investigation into the respiration rate of <i>Saccharomyces cerevisiae</i></li> <li>Genetic crosses in fruit flies and their statistical analysis</li> <li>Investigation into the rate of oxygen production in pondweed</li> </ol>

## Tracking achievement

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You need to keep the following records:

1. Plans to cover all practical requirements, such as a scheme of work to show how sufficient practical activities will be carried out to meet the requirements of the CPAC, incorporating all the skills and techniques required over the course of the A Level.
2. A record of each practical activity that is carried out and the date it was done.
3. A record of the criteria assessed in each practical activity.
4. A record of student attendance.
5. A record of which students met which criteria and which did not.
6. Evidence of students' work associated with particular activities.
7. Any associated materials provided e.g. written instructions.

You are free to choose the format in which students will record evidence of their work that best suits them. Possible suitable methods include the use of a lab book, a folder of relevant sheets or a collection of digital files.

### Our PAG trackers

We have developed spreadsheets that can be used to track the progress of a class through the Practical Endorsement. These trackers and guides on using them can be found on Teach Cambridge.

You can use our trackers as evidence for items 2–5 of the list of record keeping requirements above. Therefore by using these trackers, along with a scheme of work, any student sheets used and the students evidence, the internal monitoring of the Practical Endorsement should be very easy to administer.

## Monitoring arrangements

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### Monitoring visits

Monitoring runs in two-year cycles, with large centres (more than 140 students in any science subject) receiving visits for each science subject in each cycle. Other centres receive a visit for a single science subject in each monitoring cycle.

The purpose of the monitoring process is to ensure that centres are planning and delivering appropriate practical work, and making and recording judgements on student competences to meet the required standards.

On the day of the visit the monitor will:

- observe practical activity
- review the records kept by the centre and by students (see Tracking achievement above)
- talk with staff and students.

Following the visit, the monitor will complete a record of the visit, which will be copied to the centre. The record will state whether the monitor is satisfied that the centre is meeting the requirements for the Practical Endorsement. The report may additionally offer guidance on improvements that could be made by the centre. Should a centre dispute the outcome of a monitoring visit, a repeat visit by an alternative monitor may be requested.

## Arrangement of visits

Awarding Organisations (AOs) will use information from centre entries for A levels in biology, chemistry and physics in the previous summer examination series to jointly plan monitoring visits.

Centres will be monitored for a different science than that which was monitored in the previous monitoring cycle. The first contact with a centre will be from the AO with which the science to be monitored was previously entered. This first contact will be with the exams officer (or other nominated school contact) before arranging a mutually convenient time for the monitoring visit to take place with the lead teacher for that subject.

AOs publish cross-board messaging at the beginning of each two year monitoring cycle. The latest cross-board messaging can be found on Teach Cambridge.

## Standardisation

Lead teachers must complete the free on-line training provided (available and accessible to all teachers at: <https://practicalendorsement.ocr.org.uk>) on the implementation of the Practical Endorsement. They should also ensure that all other teachers of that science within the centre are familiar with the requirements so that:

- all students are given an adequate opportunity to fulfil the requirements of the Practical Endorsement
- standards are applied appropriately across the range of students within the centre.

## Assessing the Practical Endorsement

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The Practical Endorsement is directly assessed by teachers. The assessment is certificated as Pass or Not-classified.

To achieve a **Pass**, students will need to meet the expectations set out in the Common Practical Assessment Criteria (CPAC) (see Table 2 in the specification, Appendix 5) including demonstrating competence in all the skills, apparatus and techniques in sections 1.2.1 and 1.2.2 of each specification. Students can demonstrate these competencies in any practical activity undertaken throughout the course of study.

Students may work in groups, but must be able to demonstrate and record independent evidence of their competency. This must include evidence of independent application of investigative approaches and methods to practical work.

Teachers who award a Pass need to be confident that the student consistently and routinely exhibits the required competencies before completion of the A Level course.

## Access arrangements

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There are no formal access arrangements for the Practical Endorsement. The approach of reasonable adjustments for the Practical Endorsement is described in this [JCQ document](#).

Centres may make reasonable adjustments to their planned practical activities to allow students with disabilities to participate in practical work. Where such adjustments allow these students to independently demonstrate the competencies and technical skills required, without giving these students an unfair assessment advantage, centres may award a Pass for the Practical Endorsement.

For example, students who are colour blind can use colour charts to help them identify colour changes. Alternatively, practical activities can be selected that involve changes that such students are able to observe without such assistance.

A student whose impairment restricts their ability to perform some or all of the required practical work independently cannot achieve a Pass in the Practical Endorsement. However, they can access all the marks within the written examinations, and will benefit from having been given the opportunity to experience all practical work, perhaps with the help of a practical assistant. Details of the application process can be found [in this JCQ document](#).

More information about possible reasonable adjustments is available in [our blog](#).



## 5 Planning your practical scheme of work

In planning the practical scheme of work, centres need to ensure sufficient opportunities are provided to support students' development of understanding and skill in the following areas:

- practical skills assessed in the written examinations (identified in specification Section 1.1)
- practical techniques and procedures assessed in the written examinations (identified throughout the content modules of the specifications)
- practical skills assessed through the Practical Endorsement (identified in specification Section 1.2, for A Level only)
- conceptual understanding which can be supported through practical work.

This section presents an approach to planning a practical scheme of work that takes into account all of the above. The information in this section is presented for guidance only; there is no prescribed approach.

### A possible approach to planning

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1. Identify the learning outcomes within the specification that relate to knowledge and understanding of practical techniques and procedures.
2. Identify which of these learning outcomes relate to PAGs, so that carrying out practical work in support of these learning outcomes will also meet certain requirements within the Practical Endorsement. For both GCE Biology specifications, PAGs 1–11 relate to activity types that will also directly support learning outcomes assessed in the written examinations.
3. Select practical activities that will adequately cover the requirements identified so far.
4. Consider how to incorporate coverage of PAG12. The research, citation and investigative skills covered in PAG12 may be developed in the context of any topic in the specification (or beyond). You may elect to:
  - a. develop these skills in an area not already included in the PAGs
  - b. use this type of activity to give additional support in an area of practical activity already covered
  - c. run this type of activity as a 'mini-investigation', giving students some freedom of choice of topic.
5. Identify how the chosen practical activities can be used to support development of the practical skills assessed in the written examinations. Modify the choice of activities, or add activities, if more support is required.
6. Identify how the chosen practical activities can be used to support other learning outcomes within the specification. Again, if insufficient opportunities have been identified, consider modifying the choice of activities or adding additional activities.

Note that a much wider range of practical work can be carried out than is suggested by the learning outcomes specifically related to practical techniques and procedures.

The learning outcomes related to techniques and procedures form just one potential starting point for planning the practical scheme of work. It is equally possible to begin by considering the work you wish to carry out to support conceptual understanding, and then checking that other requirements have been covered. Alternatively, you could begin by planning sufficient work to cover the requirements of the Practical Endorsement.

## 6 Guidance on practical skills

Section 1.2.1 of the specification covers the general practical skills which students should develop and practise during their course. Section 1.2.2 of the specification covers the biology-specific apparatus and techniques with which students should be familiar and competent.

This section provides guidance which teachers can use to assist how they teach the required skills, as well as things to look out for in assessing whether students are performing the skills competently. This section is not intended as a 'mark scheme', or statement of the minimum standard required for a pass in individual activities.

### Practical skills (specification Section 1.2.1)

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#### 1.2.1(a) apply investigative approaches and methods to practical work

Students are expected to be able to think independently about solving problems in a practical context. This means that students should develop their own ideas about how to approach a task, before perhaps discussing them with other students and joining together as a group to put an agreed plan into effect.

Demonstrating investigative approaches could include:

- choosing the materials, or quantities of materials, to use
- choosing which variables to measure and which to control
- deciding what measurements or observations to make and when to make them
- choosing apparatus and devising a procedure that is safe and appropriate.

Applying investigative approaches should include completing tasks that do not include complete step by step instructions. However, activities may still be structured in some form. For example:

- providing a basic method, with students asked to modify this to measure the effect of changing a certain variable
- providing a limited range of equipment, with students asked to think about how they can use what they have been given to solve a practical problem
- providing a certain amount of information, allowing students to consider how to use familiar techniques or procedures to investigate and solve a problem.

#### 1.2.1(b) safely and correctly use a range of practical equipment and materials

Students should be shown how to use practical equipment when it is first met, through a demonstration by the teacher or technician. Good quality videos of many techniques are available online which could be used to complement such a demonstration. Teacher demonstration should also include the safe disposal of materials at the end of the laboratory session.

Hazards, and the ways in which risks should be minimised, should be explicitly explained to students whenever equipment is used for the first time, and on subsequent occasions as required. Students should also be shown how to handle materials safely so they adopt a standard routine whenever they need to use any materials. Some materials are associated with particular hazards and students should be clearly shown how they need to be handled to minimise the risk involved. In some cases, the hazards may be such that it is good practice for students to use the materials under the direct supervision of the teacher.

Increasingly, students should be able to use chemicals and common laboratory equipment safely with minimal prompting. They should be doing this routinely and consistently by the end of the course.

Students will be expected to be able to identify hazards and understand how to minimise risk. This skill can be developed by asking them to devise their own risk assessments. The risk assessment should identify the hazards associated with materials and techniques that students will be using, and describe the steps that they will take to minimise the risks involved. In some cases it may also be appropriate for them to describe how they will safely dispose of materials at the end of the laboratory session. Teachers should always check risk assessments and make sure students are aware of any errors or omissions before they begin the practical activity.

More detail about the safe use of equipment and materials is given in Appendix 1: Health and safety.

### **1.2.1(c) follow written instructions**

In many activities students will be asked to follow written instructions. It is helpful if they are first given the aims of the activity so they are clear what is expected of them and what they should expect to learn from the activity. An introduction is also a good idea so that students can fit what they are doing into a bigger picture.

It is quite common for students to be given too much information and be asked to do too many things at the same time. Research suggests that when many students follow complex instructions they are not able to think about the theoretical implications and explanations of their task at the same time. It is probably better to focus on these issues before and after the practical task itself. Providing students with instructions to look through before the practical session allows them to think about what is needed and to visualise what they will do in advance of the practical session.

### **1.2.1(d) make and record observations and measurements**

Each student must individually make measurements for each of the activities and retain a contemporaneous record of these. Appropriate scientific vocabulary should be used when recording **qualitative data**.

Units and format of recording quantitative and qualitative data are not assessed under this skill.

Students need to be able to make measurements using a range of equipment. See Appendix 3 for measurements and Appendix 4 for Units, for more detail about how to record measurements appropriately.

Observations should be recorded using appropriate scientific vocabulary. Examples of ambiguous or incorrect language include:

- mentioning colours, but not associating this with a substance or state (e.g. 'it went brown' rather than 'the solution went brown' or 'a brown precipitate formed')
- giving an accurate observation of the state of a solution or mixture, but not indicating that nothing has changed (e.g. 'blue solution' rather than 'solution remains blue' or 'no change')
- using 'clear' instead of 'colourless'.

### **1.2.1(e) keep appropriate records of experimental activities**

Each student should have a permanent record of each activity they have completed, and where appropriate with suitable tables and graphs and/or calculated results. These records should be made during the laboratory session and are the primary evidence of the outcomes of experiments. Some errors/inconsistencies in the presentation of data are acceptable.

Where experimental procedures have been provided they do not need to be written out again, but they should be kept as part of the record.

Where the activities are 'investigations' there should be a suitable description of the manner in which these were carried out and why – citing which variables were dependent and which independent, whether or not ranges were adjusted to produce suitable results and how.

There should be enough detail to interpret the results produced.

The record may also show how the student has processed raw data, perhaps by using graphs or calculations, and the conclusions they have drawn. In some cases students may also evaluate their practical activity by calculating errors and/or commenting on the limitations of experimental procedures. These skills are not assessed in the Practical Endorsement, but are valuable in understanding the purpose of a practical activity, and will be assessed in the written examinations.

Records may be kept in a laboratory notebook, in a loose-leaf file or electronically. Students should record measurements and observations during laboratory sessions immediately, but these could be transferred to the permanent record later; for example, if there is no means of entering data into an electronic record in the lab.

### **1.2.1(f) present information and data in a scientific way**

Students should present information and data in ways that are appropriate for that information or data. In many cases this will involve the use of tables. These should include an explanatory title, clear headings for columns and relevant units for measurements (see Appendix 3: Measurement and Appendix 4: Units for further details).

Graphs should be of an appropriate type for the information or data involved. Further detail about drawing and using graphs is given in Appendix 5: Tables and Graphs.

Some information is best presented by using clear, well labelled diagrams (See [Biological skills Drawing Skills Handbook](#)) or potentially using annotated photographs.

### **1.2.1(g) use appropriate software and tools to process data, carry out research and report findings**

The most obvious tools and software used for processing data are calculators and spreadsheets. Spreadsheets provide a very effective way of processing data, particularly when the amount of data is large. They can be used to sort data, carry out calculations and generate graphs. Graphs drawn using spreadsheets should not be too small, should have a clear title and the axes should be clearly labelled. Where more than one graph is drawn using the same axes it should be clear what each graph refers to.

If records are kept electronically, students will routinely make use of a word processing package to report their findings. Short video clips can be used to show changes over time. Digital images, podcasts and PowerPoint® presentations also provide creative ways in which students can personalise their individual record of practical activities.

Rates experiments lend themselves to use of a data logger, particularly when very short or very long timescales of data collection are involved. Students need training in how to use both the hardware and associated software to collect data, particularly if choices need to be made about measurement scales or when a trigger is used to start data collection. It is usually better to present collected data graphically rather than recording a large amount of raw data.

### **1.2.1(h) use online and offline research skills including websites, textbooks and other printed scientific sources of information**

Students should be given opportunities to use both online and offline research skills in the context of practical activities. A useful starting point might be finding reliable information to devise a risk assessment for an experiment. Safety data sheets, such as the CLEAPSS® Student Safety Sheets (accessible without a login) are a good place to start. More detail about sources of information is given in Appendix 1: Health and safety.

In other situations students might consult websites, textbooks or scientific journals to clarify or suggest experimental techniques and/or to provide supporting background theory to practical activities.

### **1.2.1(i) correctly cite sources of information**

Where a student records information that they have looked up they should provide an accurate reference so that readers can find the information. Examples of how to do this are given in Appendix 6: Referencing.

### **1.2.1(j) use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification**

It is expected that students will carry out practical work throughout their course and will therefore use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification. The minimum of apparatus and techniques that each student must use is listed in specification Section 1.2.2. Suggested apparatus for use during the course is also provided in Appendix 2: Apparatus list.

## **Use of apparatus and techniques (specification Section 1.2.2)**

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Note: There is a wealth of really useful and encouraging information on many of these topics from CLEAPSS. Please do make use of it; it will enable you to confidently carry out a varied and interesting programme of practical work while intelligently managing and minimising risks.

### **1.2.2(a) use of appropriate apparatus to record a range of quantitative measurements (to include mass, time, volume, temperature, length and pH)**

Volumes might be directly measured with gas syringe or inverted measuring cylinder, inverted burette or a pre-calibrated potometer capillary or might be derived using linear measurements (length and diameter) and the appropriate formula.

Before measuring mass, the tare facility should be used to zero the balance. It is good practice to use a disposable weighing boat to weigh solids and a weighing bottle to weigh liquids. The weighing boat or bottle should be weighed before materials are added and weighed again after they have been emptied into another container so that an accurate mass of the material used can be found by subtraction of masses.

Time will be measured in activities such as effect of exercise and rates of enzyme reactions. It is important to remember, if not using data loggers, that time should be measured to the nearest whole or 0.5 of a second due to human reaction time.

When measuring volumes, the mark on the apparatus should be at eye level to minimise parallax error. It is important that students can read a measurement from the meniscus correctly e.g. when using a burette. This can be included when studying the properties of water. When an inverted burette or measuring cylinder is clamped over water, there should be sufficient space between the open end of the burette and the bottom of the water container to allow a delivery tube to be moved into place. A washing up bowl or ice cream container are good alternatives to a glass trough in many cases. An opportunity for practice of this will come when studying enzymes and rates of reactions. Care should be taken to select the appropriate piece of apparatus for the chosen practical, e.g. trialling first to select the correct sized measuring cylinder to collect the most accurate results when collecting a gas over water.

## 1.2.2(b) use of appropriate instrumentation to record quantitative measurements, such as a colorimeter or potometer

### *Colorimeter:*

Some use cuvettes, some will accept test tubes. In either case ensure the tube or cuvette is clean and not scratched. Note that cuvettes often have two clear walls for the lightpath – insert such cuvettes in the correct orientation.

Ensure any solids or precipitate are not in the light path (e.g. by filtration or centrifugation) or conversely, when measuring turbidity, ensure the solid phase is fully suspended

Select the appropriate wavelength of light for measurements (follow instructions or do a trial run to find maximal absorbance).

Zeroing the colorimeter requires a moment of thought to choose an appropriate zero sample – it could be distilled water but it might not be.

Calibration curves can be constructed from readings of a dilution series of a known solution.

### *Potometer:*

When setting up a potometer to measure the rate of uptake of water from a leafy shoot it is important to minimise the contact between the air and the cut end of the stem. There should be no air bubble and all joints should be sealed with e.g. Vaseline. It is a good idea to trial this first; the shoot should have a number of leaves on for better results. There are some useful videos on YouTube on the setting up of a potometer and the SAPS website has an excellent example.

<http://www.saps.org.uk/secondary/teaching-resources/1263-investigating-transpiration-with-a-potometer>

Cut a leafy shoot with secateurs and plunge straight away into water using e.g. a deep bowl or bucket to prevent air bubbles from being trapped in the xylem. Do not get the leaves wet. When ready to use, very quickly transfer the shoot into a large bowl of water or sink keeping the base of the stem under water and the leaves dry, cut carefully, with a razor blade, a couple of cm off the bottom of the stem at an oblique angle still under water.

Immerse the potometer under water and make sure all air bubbles are removed and still underwater insert the end of the shoot into the rubber tubing, making sure the leaves are still kept dry. The end of the shoot should be able to fit tightly into the rubber tubing or stopper of the potometer.

Make sure any reservoir taps are closed before the potometer is removed from the water.

Grease all joints well.

Allow the shoot to equilibrate for about 5 minutes before taking readings; return the air bubble to its original position with the syringe before each reading.

### *Respirometer:*

Ensure that all joints are sealed properly. Vaseline can be applied as necessary. If using soda lime make sure it is fresh and not exposed to the air before use. If using food dye in the capillary tube then add a little ethanol for it to flow more smoothly. Trial before use.

If using small invertebrates e.g. woodlice or maggots, it is essential to ensure that the animals do not come into contact with the soda lime. Place the soda lime in the bottom of the boiling tube, cover with a little cotton wool and then put in the metal gauze 'basket' which will hold the animals.

Allow time for organisms to equilibrate to the environment before timing and measuring movement of dye up the capillary tube.

### *Measurement of pH:*

pH charts, pH meter, or pH probe on a data logger can all be used and have their own pros and cons depending on the details of the investigation.

Students will be familiar with the use of pH charts from key Stage 4 but can obtain more precise, accurate and high-resolution information using a pH meter. pH meters must be calibrated before use by dipping into a buffer solution of known pH and adjusting the reading so that it is correct for that solution. Meters should be rinsed with distilled water between each measurement to avoid contamination between samples. In most situations, one pH meter can be shared between several students. This minimises the number of instruments required, but it does mean that great attention must be paid to cleaning the probe before each use.

### **1.2.2(c) use of laboratory glassware apparatus for a variety of experimental techniques to include serial dilutions**

#### *Use of a burette:*

Before using a burette, it should be rinsed first with distilled water and then with the solution it is going to contain. Solution should be added to the burette so it is above the zero mark and then some of it allowed to run through the tap until the tip of the burette is full of solution and contains no bubbles. The initial reading on the burette does not need to be exactly 0.00 cm<sup>3</sup>.

A small funnel can be used when solution is added to the burette. A filter funnel is not suitable for this purpose. The funnel should be removed as soon as the solution has been added.

The volume of the solution in the burette should be read to the nearest 0.05 cm<sup>3</sup>. Placing a white tile or piece of white paper behind the burette makes it easier to see the scale.

#### *Serial dilutions:*

Serial dilutions are often required, e.g. in enzyme reactions or as standards for a calibration curve, and are particularly useful in microbiology when counting the number of bacterial colonies.

### **1.2.2(d) use of a light microscope at high power and low power, including use of a graticule**

#### *Making slides for microscope use:*

Students often benefit from being reminded that a small sample yields the best results.

Improvised microtomes, achieved by wedging the sample to be sectioned into a piece of potato or expanded polystyrene and then taking thin sections with a fresh razor blade, can produce excellent results if students are careful, persistent and willing to have several 'duds' in the hope of one or two successes.

Remember to ensure that the sample is as flat as possible on the glass slide. Use forceps to help position the sample.

For a wet mount only use one or two drops of stain at one end of the sample.

Carefully and slowly lower the cover slip down onto the sample at an angle using a mounting needle to help lower it. This is to avoid any air bubbles.

To remove any excess stain and to pull the stain evenly over the sample place a small piece of absorbent paper e.g. blotting paper or paper towel at the edge of the other end of the cover slip to where the stain was first applied, this will pull the liquid across the sample and absorb the excess.

#### *To use a microscope:*

Clean lenses with lens tissue.

Place slide to be observed under both clips on the stage, ensuring first that the slide is clean.

Turn the lowest power objective lens on the nosepiece so it is clicked into position.

Looking from the side of the microscope gently turn the coarse adjustment knobs until the lens is just above the slide. It must not touch the slide.

Look down the microscope and adjust the mirror or condenser to obtain the best even illumination.

Look down the microscope again and slowly turn the coarse adjustment knobs so the low objective lens and the slide move gradually further apart. Continue slowly until the object on the slide is in focus. Then turn the fine adjustment knobs to obtain the best image, the slide might have to be slightly moved to centre the part to be observed.

Once the low power focus has been determined there should be very little adjustment to achieve high power magnification. Move the slide to the area to be viewed under high power. Gently rotate the nose piece until the high power objective lens clicks into position. The fine adjustment knob may have to be turned to improve the focus of the object being viewed. The light may also have to be slightly adjusted by moving the mirror and/or diaphragm.

Remember – it is better to learn to keep both eyes open when using a microscope as it helps to prevent eye strain. Glasses need to be worn when the observer has an astigmatism, for short and long sightedness it is optional. Do not try to find an object under high power when it cannot be found under low power.

How to work out magnification:

	<b>Eyepiece lens</b>	<b>Objective lens</b>	<b>Total magnification</b>
<b>Low power</b>	10 x	10 x	100 x
<b>High power</b>	10 x	40 x	400 x

Students may well already know this straightforward calculation of magnification. However, to include a meaningful scale on their drawings of microscopic specimens this statement of the magnification of the image they see is not sufficient. It will be necessary for them to make measurements of the specimen using a graticule and transfer this information to their scale drawings.

Calibrating the eyepiece graticule is straightforward but can be confusing at first. A stage micrometer is simply a slide with a set of evenly-spaced markings, usually 0.1 mm apart. By viewing this stage micrometer with an eyepiece graticule in place and using the desired objective lens it is possible to line up the graticule markings with those on the stage micrometer. Thus it is possible to calculate the calibration factor, indicating how far apart the graticule markings are when using this particular objective lens. The stage micrometer can then be removed and the specimen slide put in its place. Measurements of the specimen can be taken using the calibrated graticule.

### **1.2.2(e) production of scientific drawings from observations with annotations**

Information and examples are provided in the [Drawing Skills Handbook](#).

### **1.2.2(f) use of qualitative reagents to identify biological molecules**

For reasons of safety it is advisable to use water baths for heating and safety glasses should be worn.

Food samples should be ground down or finely broken up and made into a solution or fine suspension with water before being tested. (The test for starch can also be performed by adding the iodine solution/potassium iodide directly to the solid specimen.)



### *Carbohydrates:*

#### Sugars

Monosaccharides e.g. fructose, glucose and galactose and some disaccharides e.g. maltose are known as reducing sugars. When heated with Benedict's reagent they will reduce the blue copper sulphate which is soluble to an insoluble copper oxide (red-brown) precipitate.

To test for the presence of a reducing sugar add equal quantities of Benedict's reagent to a solution of the substance to be tested in a boiling or test tube. Gently shake the boiling tube to mix the contents and place in boiling water for about 5 min. Do not put the boiling tube directly in a flame to heat as the solution is likely to spit and bump violently. The presence of a reducing sugar produces a precipitate which, depending on quantity, will vary in colour from green to yellow to orange to brick red/brown. Brick red/brown shows a high concentration of reducing sugar.

Test strips are also available for testing for reducing sugars (Clinistix being one example). Instructions in or on the packets must be carefully followed. While these can be very convenient in some cases, it is important that students are fully competent in carrying out the Benedict's test.

Disaccharides such as sucrose will give a negative result when tested with Benedict's reagent, therefore they must be hydrolysed first, neutralised and then re-tested with Benedict's reagent. For this the substance e.g. sucrose solution must first be brought to the boil in a water bath with a few drops of dilute hydrochloric acid. The solution is then neutralised with sodium hydrogen carbonate, tested with pH paper, and then re-tested with Benedict's reagent as for a reducing sugar.

#### Starch

Starch is relatively insoluble in water and forms a colloidal suspension. Add dilute iodine solution/potassium iodide to the substance to be tested or to the colloidal suspension. A blue-black colouration is a positive result, indicating the presence of starch.

### *Proteins:*

The biuret solution contains potassium hydroxide solution and copper sulphate. CLEAPSS have useful information (CLEAPSS Recipe Book 15 Biuret Reagent) for preparing different versions of the reagent. When added to a solution of soluble protein a mauve or purple colouration will be observed. The mauve/purple colouration indicating the presence of protein appears slowly and is not instant. If the potassium hydroxide solution is added to the copper sulphate solution before testing then it must be used immediately and not stored. Better results will be achieved if the potassium hydroxide is added to the protein solution first, and then a couple of drops of copper sulphate solution are gently added down the side of the test tube. If a protein is present a blue ring will first appear which when gently shaken will gradually turn the solution a mauve/purple colour.

### *Lipids:*

The substance to be tested should be shaken well in absolute ethanol for approximately a minute, and then the ethanol drained off into a test tube containing water, (leaving the substance being tested behind). A white cloudy emulsion will appear if the test is positive. When shaking the test tube to mix the ethanol with the food substance a bung should be used.

## **1.2.2(g) separation of biological compounds using thin layer/paper chromatography or electrophoresis**

Ensure the instructions for safe use of any UV sources used to view chromatograms or electrophoresis gels are followed correctly.

### *Chromatography:*

Unfortunately the best extraction and running solvents often include hazardous organic solvents. Use a fume cupboard to minimise exposure and ventilate the lab as well as possible. Ensure that the solvents are disposed of correctly after use. Students should be aware of these issues even though they will not be involved in the bulk preparation or disposal of solvents.

A small intense spot will give the best results. In most cases the concentration of the sample in extraction solvent will be so low that multiple spots will need to be superimposed to achieve the required intensity. Ensure that the previous spot has dried before adding the next spot on top of it otherwise the spot will spread out and ultimately give a smudged separation.

Chromatography paper and TLC plates should be handled carefully as oils on fingers and hands will cause aberrant results.

If possible photographs should be taken of the final results before pigments fade, and students could do this with their mobile phones.

#### *DNA Electrophoresis:*

Note: this could be carried out at a local university or science centre, many of which run such courses for groups of A Level students. Check for such opportunities in your local area.

Be sure to follow the electrical safety instructions carefully with whatever equipment is being used. When pouring the gels exercise caution with hot agarose. The key for good results is loading the sample accurately into the wells. For first timers a trial run with dye alone can be a good exercise rather than wasting precious DNA samples.

It is usual to run a 'marker' sample of known DNA fragments in one of the lanes.

Use of ethidium bromide to visualise the separated bands of DNA is not recommended in schools due to its toxicity. Safer visualisation dyes are available but all should be treated with caution. Follow the most up to date CLEAPSS advice.

### **1.2.2(h) safe and ethical use of organisms to measure: (i) plant or animal responses, (ii) physiological functions**

With their consent students can use their fellow students as experimental subjects. However, regardless of consent, no hazardous or harmful procedures can be carried out by A Level students on human subjects. For example an investigation into the effects of exercise on pulse rate could be carried out using willing subjects but an investigation into the effects of smoking on pulse rate could not.

Use of animals in laboratory investigations is restricted to small invertebrates. Care should be taken over the source of these animals and their treatment when being kept and used.

Plants used in laboratory investigations should be responsibly sourced.

When animals and plants are involved in fieldwork (either because they are the specific subject of the investigation or because they and their habitat are affected by the investigation) the aim is, as far as possible, to leave them undamaged and unmoved. For example if a rock is turned over on a shoreline it should be replaced as it was to ensure that anything clinging to the underside is once again underneath and any barnacles etc. on top are equally undisturbed.

### **1.2.2(i) use of microbiological aseptic techniques, including the use of agar plates and broth**

This is an area where experience and confidence varies widely and it is strongly recommended to refer to the excellent and extensive information available from CLEAPSS.

The principle that the air in the laboratory contains many microscopic organisms capable of contaminating a culture is an important and interesting one. A simple investigation to demonstrate this is to expose agar plates to the air for different lengths of time. This should embed the idea that minimising the exposure time will minimise the risk of contamination. By working next to a Bunsen burner to create an updraft the exposure time can be prolonged without contaminating the plate. This is of course particularly convenient if the Bunsen is also being used to flame sterilise a loop.

Students will probably have encountered agar plates before and should be familiar with the standard guidance for safe practice: lids secured but not sealed, incubation at room temperature, observation without opening and subsequent destruction of the microorganisms by autoclave (if available) or by using a pressure cooker.

Many students will not previously have used broth cultures and it is important not to underestimate the difficulty of doing these manipulations for the first time. Even focused students can get in a muddle and spills are possible. Working in a tray with a capacity significantly greater than the volume of broth being used can greatly reduce the impact of an unlucky spill.

### 1.2.2(j) safe use of instruments for dissection of an animal or plant organ

The hazard of sharp instruments is an obvious issue with dissection. Good hygiene is also essential when dealing with animal tissues. If the specimens have been treated with any preservative check what it is and what precautions should be taken in terms of contact and disposal.

Students will often be working in pairs, or sometimes larger groups, which is perfectly compatible with the requirements of the endorsement. Each student should have the chance to demonstrate safe and scientific dissection. For safety reasons it is best practice to have a rule that only one student at a time is 'hands on'.

Students will often make a bee line for the scalpel, seeing this as the 'proper' dissection tool but it is often easier and safer to do the majority of the work with good, sharp dissecting scissors and then to use the scalpel only for fine work.

Note that it is perfectly acceptable to carry out plant organ dissection instead of, or in addition to, animal organ dissection(s), for example root, stem or flower dissection.

### 1.2.2(k) use of sampling techniques in fieldwork

Before embarking on any work in the field, as in any practical, a Health and Safety risk assessment must be made. If in any doubt most educational local authorities should be able to help. In addition other external organisations such as Field Study Centres have Health and Safety risk assessments.

Forward planning is imperative. Visit the site well in advance and again just before taking students out. When leaving a site ensure that all apparatus is collected in and 'leave nothing but footprints.' It is useful to use pencils rather than pens and put clipboards in plastic bags if weather is inclement so recording sheets can be kept legible, clean and dry. Students should consider the concept of equal sampling effort to ensure comparable results. It is easy to start off keen and for the sampling effort to fall as the day goes on.

#### *Random Sampling*

This is usually carried out when the area under study is large, fairly uniform and/or there is limited time available. Sampling positions are chosen using coordinates from a random number table (e.g. [www.countrysideinfo.co.uk/2howto.htm](http://www.countrysideinfo.co.uk/2howto.htm)) or a pseudo-random number generator on a calculator.

#### *Systematic Sampling*

**A line transect** can be used for identifying the change of species (or not) in a straight line in a habitat, e.g. across a sand dune system or down a rocky shore, or where the environment changes e.g. from grassland into woodland. For a line transect a rope or tape measure is laid along the ground in a straight line between two points which can be identified by two range poles.

A quadrat can then be placed at regular intervals along the rope and the frequency of species estimated this is known as a **belt transect**. Instead of a quadrat a point quadrat can be used e.g. in short grassland for plant sampling. This is a simple straight wooden or metal horizontal frame with long pointed needles pushed through it at regular intervals.

When using a line transect on a rocky shore the first reading should be started nearest the water at low tide and then work up the shore. Clinometers can be used to measure the gradient or profile of the transect, this is known as a **profile transect**.

#### *Other common methods of sampling*

In water - kick sampling: using a net to collect invertebrates disturbed from a river bed by kicking.  
Sweep netting: using a net for sampling invertebrates found in water above the river bed.

On land and in the air - sweep netting for sampling invertebrates in the air and in tall grassland.

Beating for sampling invertebrates in shrubs and the lower branches of trees. This is done by shaking or thumping on a tree/shrub so that the invertebrates drop on to a sheet below. These are then quickly collected in a pooter and counted. Capture and recapture, this is where animals are

captured, marked, released and then the population is recaptured again and the number of marked animals counted. Woodlice can be easily used for this method.

All animals removed from their environment for counting should be returned as soon as possible and should be undamaged. Water animals if removed from e.g. rock pools should be kept in water from those rock pools until returned.

### **1.2.2(I) use of ICT such as computer modelling, or a data logger to collect data, or use of software to process data**

There is a huge range of possible activities which would allow students to acquire and demonstrate these skills and techniques. Some suggestions can be found below and this section will be updated as we become aware of additional biologically-relevant software and/or hardware.

There are several commercial data logging systems designed and marketed specifically for school and college use. In addition there is an increasingly wide selection of plug-in instruments and apps for transforming smart phones and similar devices into data loggers, for example exercise monitors. All of these could be used in ways that would address the requirements of the practical endorsement so the choice when investing in new kit comes down to what you want to do with it, how much you wish to spend and how it integrates with any existing kit and your school/college IT system. Examples could include pH monitors and light intensity meters.

If you do not have data loggers this part of the endorsement can still be very adequately addressed by activities involving students in significant engagement with software tools, electronic data-gathering devices and large data sets. This can be through the use of molecular modelling programs (for example RasMol, PyMol and JMol) or epidemiological simulations or by using software for analysis of fieldwork data (suitable plug-ins to allow kite diagram plotting within Microsoft Excel are available). You can find guidance and instructions for an alternative practical activity using Mol\* browser, in our [blog](#).

# Appendix 1: Health and safety

This appendix provides information on handling Health and safety issues while carrying out practical experiments.












**Before carrying out any experiment or demonstration based on this guidance, it is the responsibility of teachers to ensure that they have undertaken a risk assessment in accordance with their employer's requirements, making use of up-to-date information and taking account of their own particular circumstances. Any local rules or restrictions issued by the employer must always be followed.**

Useful information can be found at [www.cleapss.org.uk](http://www.cleapss.org.uk) (available to CLEAPSS® members only).

## Hazard labelling systems

The CLP regulations were launched in 2010, and fully implemented across the EU in 2015. The 'CHIP' system is no longer in active use, but some older containers may still carry the CHIP symbols, and students may come across them in older reference works. It is important that students are taught to use both systems, particularly if centres are still using chemicals carrying CHIP hazard symbols.

OCR recognises the CLP system as the default system in current use. OCR resources indicate hazards using the CLP system.

	Oxidising		Toxic	<b>CLP pictograms are also accompanied by a 'signal word' to indicate the severity of the hazard.</b>  <b>'DANGER'</b> for more severe; <b>'WARNING'</b> for less severe.
	Highly flammable		Indicates that the chemical could cause serious <i>long term</i> health effects.	
	Corrosive		Indicates less serious health hazards (e.g. skin irritants).	
	Oxidising		Toxic	<b>'CHIP' system (being phased out)</b>
	Highly Flammable		Harmful or Irritant	
	Corrosive			

## Risk assessments

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In UK law, health and safety is the responsibility of the employer. Employees, i.e. teachers, lecturers and technicians, have a duty to cooperate with their employer on health and safety matters. Various regulations, but especially the COSHH Regulations 2002 and the Management of Health and Safety at Work Regulations 1999, require that before any activity involving a hazardous procedure or harmful micro-organisms is carried out, or hazardous chemicals are used or made, the employer must provide a risk assessment. A useful summary of the requirements for risk assessment in school or college science can be found at

<http://www.ase.org.uk/resources/health-and-safety-resources>

For members, the CLEAPSS® guide, *Managing Risk Assessment in Science*\* offers detailed advice. Most education employers have adopted a range of nationally available publications as the basis for their Model Risk Assessments. Those commonly used include:

- *Safety in Science Education*, DfEE, 1996, HMSO, ISBN 0 11 270915 X.

Now out of print but sections are available at

<http://www.ase.org.uk/resources/health-and-safety-resources>;

- *Topics in Safety*, 3rd edition, 2001, ASE ISBN 0 86357 316 9;
- *Safeguards in the School Laboratory*, 11th edition, 2006, ASE ISBN 978 0 86357 408 5;
- CLEAPSS® *Hazcards*.\*

CLEAPSS® are in the process of updating the *Hazcards*, the latest edition being the CLP Edition, 2014. At present, CLP Hazcards have only been published for some chemicals. For other chemicals, the CHIP Hazcard is referenced and should be consulted.

- CLEAPSS® *Laboratory Handbook*\*;
- *Hazardous Chemicals*, A Manual for Science Education, 1997, SSERC Limited ISBN 0 9531776 0 2.

Where an employer has adopted these or other publications as the basis of their model risk assessments, the teacher or lecturer responsible for overseeing the activity in the school or college then has to review them, to see if there is a need to modify or adapt them in some way to suit the particular conditions of the establishment.

Such adaptations might include a reduced scale of working, deciding that the fume cupboard provision is inadequate or the skills of the students are insufficient to attempt particular activities safely. The significant findings of such risk assessment should then be recorded, for example on schemes of work, published teachers' guides, work sheets, etc. There is no specific legal requirement that detailed risk assessment forms should be completed, although a few employers require this.

Where project work or individual investigations, sometimes linked to work-related activities, are included in specifications this may well lead to the use of novel procedures, chemicals or microorganisms, which are not covered by the employer's model risk assessments. The employer should have given guidance on how to proceed in such cases. Often, for members, it will involve contacting CLEAPSS® (or, in Scotland, SSERC).

\*These, and other CLEAPSS® publications, are on the CLEAPSS website. Note that CLEAPSS® publications are only available to members. For more information about CLEAPSS - go to [www.cleapss.org.uk](http://www.cleapss.org.uk). In Scotland, SSERC ([www.sserc.org.uk](http://www.sserc.org.uk)) has a similar role to CLEAPSS®.

## Appendix 2: Apparatus list

This appendix lists the apparatus likely to be required in order to complete a practical scheme of work that covers all requirements of the qualification. Teachers and technicians should bear in mind that activities that would support the qualification may require additional apparatus not on this list. Resources provided by OCR detail the apparatus needed for individual activities.

### Apparatus likely to be required

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The following apparatus is likely to be required to complete activities covering all techniques required by the Practical Endorsement in GCE Biology (Section 1.2.2 of the specification).

- Microscopes with at least two objective lenses and an eyepiece graticule
- Microscope slides and coverslips
- Dissection equipment
- Balances reading to at least two decimal places
- Stop clocks/watches reading to 1 s or better.
- Beakers (400 cm<sup>3</sup>, 250 cm<sup>3</sup>, 100 cm<sup>3</sup>)
- Measuring cylinders (250 cm<sup>3</sup>, 50 cm<sup>3</sup>, 25 cm<sup>3</sup>, 10 cm<sup>3</sup>)
- Gas syringes (100 cm<sup>3</sup>) (can be replaced by inverted burettes, measuring cylinders)
- Thermometers (–10 to 110 °C or equivalent, accurate to 0.5 °C)
- Heating apparatus: water baths, or electric heaters, or sand baths  
*A water bath could consist of a beaker of water on a tripod and gauze over a Bunsen flame.*
- pH indicator paper, or pH meter, or pH probe
- Retort stands and clamps
- Test tubes and boiling tubes
- Test-tube holders
- Stoppers
- Dropping pipettes
- Funnels
- Filter paper
- Volumetric flasks (250 cm<sup>3</sup> or 100 cm<sup>3</sup>)
- Conical flasks (250 cm<sup>3</sup>, 100 cm<sup>3</sup>)
- Watchglasses
- Razor blades
- Capillary tubes
- Chromatography paper or thin layer chromatography plates
- Suitably-sized chromatography tanks
- Wash bottles with distilled water
- Quadrats
- 30 m measuring tapes
- Petri dishes and broth culture bottles

## Apparatus potentially required

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The following laboratory equipment may additionally be required to support further practical work towards the Endorsement as well as to support teaching of the specification and preparation for the written examinations.

- Plastic/styrofoam cups for use as a calorimeter
- Pipeclay triangles
- Porcelain crucibles + lid
- Bunsen burners
- Glass rods
- Heat proof mats
- Tripods and gauze
- Colorimeters
- Potometers
- Electrophoresis equipment
- Data loggers
- Pipettes and micropipettes
- Syringes (10 cm<sup>3</sup>, 5 cm<sup>3</sup>, 2 cm<sup>3</sup>, 1 cm<sup>3</sup>)
- Pipette fillers
- Burettes (50 cm<sup>3</sup>)
- Haemocytometer slide
- Microbiology incubator
- Spirometer
- Plant growth chamber and/or greenhouse

## Additional requirements

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In order to fulfil the requirements of the skills set out in Section **1.2.1** of the specification, students will require access to the following.

- Chemical data or hazard sheets
- Graph plotting and data analysis software (e.g. Microsoft Excel)
- Textbooks, websites and other sources of scientific information
- A means of recording practical activity undertaken towards the Practical Endorsement, for example a logbook, binder to collect loose sheets, or means to create and store digital files.

## Lab Books

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Students can keep their records in any appropriate form including the use of a ring binder or other folder. Should your centre wish to purchase lab books there are educational suppliers who stock a wide variety of these.

Some publishers offer lab book resources which include practical activities and space for students to record results. Take care if using these resources as they are not endorsed and in some cases the level of scaffolding provided for the recording of results could prevent students from being able to independently demonstrate some 1.2.1 skills. You should check the mapping of these activities to the 1.2.1 and 1.2.2 practical skills as in some cases the publisher's mapping is not accurate.



## Appendix 3: Measurements

This appendix provides background information on terms used in measurement, and conventions for recording and processing experimental measurements. This information relates to skills assessed both in the written examinations and in the Practical Endorsement, notably 1.1.2(c), 1.1.3(c), 1.1.4(b), 1.1.4(d), 1.2.1(d), 1.2.1(f). Further guidance on the language of measurement is also provided on Language of measurement in context resource available on [Teach Cambridge](#).

### Useful terms

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**Accuracy** is a measure of the closeness of agreement between an individual test result and the true value. If a test result is **accurate**, it is in close agreement with the true value. An accepted reference value may be used as the true value, though in practice the true value is usually not known.

**Anomaly (outlier)** is a value in a set of results that is judged not to be part of the inherent variation.

**Confidence** is a qualitative judgement expressing the extent to which a conclusion is justified by the quality of the evidence.

**Error** (of measurement) is the difference between an individual measurement and the true value (or accepted reference value) of the quantity being measured.

**Precision** is the closeness of agreement between independent measurements obtained under the same conditions. It depends only on the distribution of random errors (*i.e.* the spread of measurements) and does not relate to the true value.

**Repeatability** is the precision obtained when measurement results are produced over a short timescale by one person (or the same group) using the same equipment in the same place.

**Reproducibility** is the precision obtained when measurement results are produced over a wider timescale by different people using equivalent equipment in different (but equivalent) places.

**Resolution** is the smallest change in the quantity being measured that can be detected by an instrument.

**Uncertainty** is an estimate attached to a measurement which characterises the range of values within which the true value is asserted to lie. This is normally expressed as a range of values such as  $44.0 \pm 0.4$ .

**Validity** can apply to an individual measurement or a whole investigation. A measurement is valid if it measures what it is supposed to be measuring. An investigative procedure is valid if it is suitable to answer the question being asked. Validity will be reduced, for example, if no negative control is included in an investigation into the efficacy of a therapeutic drug.

The ASE booklet *The Language of Measurement* (Campbell 2010) provides information on these and other terms along with examples of their use. In particular please note that **reliability** will no longer be used. As the authors of the booklet say:

*“The word ‘reliability’ has posed particular difficulties because it has an everyday usage and had been used in school science to describe raw data, data patterns and conclusions, as well as information sources. On the strong advice of the UK metrology institutes, we avoid using the word ‘reliability’ because of its ambiguity. For data the terms ‘repeatable’ and ‘reproducible’ are clear and therefore better. For conclusions from an experiment, evaluative statements can mention ‘confidence’ in the quality of the evidence.”*

# Uncertainties

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Whenever a measurement is made, there will always be some doubt about the result that has been obtained. An uncertainty in a measurement is an interval that indicates a range within which we are reasonably confident that the true value lies.

Uncertainties technically depend on a range of factors related to measurements, including both systematic and random errors. Determining uncertainties based on the spread of data obtained is not required within the context of AS and A Level Biology. Rather, an estimation of uncertainty is made based on the characteristics of the equipment used.

## Uncertainties in apparatus and equipment

When using any apparatus, students should check whether the apparatus itself is marked with the uncertainty. This is, for example, generally the case in for volumetric glassware used to measure specific volumes of liquid, such as volumetric flasks and pipettes frequently used in A Level Chemistry. The degree of uncertainty in these cases depends on the class of apparatus.

For example, a 100 cm<sup>3</sup> measuring cylinder is graduated in divisions every 1 cm<sup>3</sup>.

- A Class A measuring cylinder has an uncertainty of half a division or 0.5 cm<sup>3</sup> in each measurement
- A Class B measuring cylinder has an uncertainty of a whole division or 1 cm<sup>3</sup> in each measurement.

In the absence of information provided on the equipment, the following assumptions are made regarding the uncertainty in each measurement:

- When using apparatus with an analogue graduated scale, the uncertainty is assumed to be  $\pm$  half the smallest graduation.

For example a 30 cm rule has divisions of 1 mm and an uncertainty of half a division, or 0.5 mm. When measuring a distance the uncertainty has to be taken into account twice and it is overall 1 mm.

An analogue meter with scale markings each 0.2 V has an uncertainty of 0.1 V.

- When using digital apparatus, the uncertainty is presumed to be  $\pm$  the resolution of the apparatus in each measurement.

For example, a two-decimal place balance has an uncertainty of  $\pm 0.01$  g in each measurement and a voltmeter with three significant figures which has an uncertainty of  $\pm 0.1$  V in the 0-20 V range will have an uncertainty of  $\pm 1$  V in the 0-100 V range.

The basis of the assumption for electronic apparatus is that the electronic circuit is designed to avoid “hunting” which is the rapid cycling from one figure to another in the final digit. This is achieved by programming the equipment to go up to the next value at a level greater than 0.5, and to go to the lower value at a level below 0.5; this could be going up at 0.7 and down at 0.3. As we are not aware of that value we can only assume  $\pm 1$  digit in the final digit.

Students should be able to calculate a percentage uncertainty for a measurement from the absolute uncertainty for the apparatus used. See worked examples on the next page.

Because of the variability in uncertainties associated with equipment, assessments will frequently state the absolute uncertainty in any measurement given to allow students to calculate the percentage uncertainty. If no information is given, the uncertainty in each reading is derived from the resolution of the apparatus used as explained above.

## Measurement of time

Whilst a stopwatch measures time with a resolution of say 0.001 s, the operator reaction time is significantly longer, increasing the total uncertainty in the measurement, in which case a reasonable estimate for the uncertainty would be the reaction time of the operator.

A light gate measures time with the same resolution of 0.001 s, but has a significantly lower total uncertainty as it eliminates the reaction time of the operator.

## Examples of uncertainties

Some examples are shown below. Note that the actual uncertainty on a particular item of glassware may differ from the values given below.

Volumetric or standard flask (Class B)

- A 250 cm<sup>3</sup> volumetric flask has an uncertainty of  $\pm 0.2$  cm<sup>3</sup> or 0.08%.

Pipette (Class B)

- A 25 cm<sup>3</sup> pipette has an uncertainty of  $\pm 0.06$  cm<sup>3</sup> or 0.24%.

## Worked examples

The significance of the uncertainty in a measurement depends upon how large a quantity is being measured. It is useful to quantify this uncertainty as a percentage uncertainty.

$$\text{percentage uncertainty} = \frac{\text{uncertainty}}{\text{quantity measured}} \times 100\%$$

For example, a measurement of 2.56 g is taken using a two-decimal place balance with an uncertainty of  $\pm 0.01$  g.

- percentage uncertainty =  $\frac{0.01}{2.56} \times 100\% = 0.39\%$

For a mass measurement of 0.12 g, the percentage uncertainty is much greater:

- percentage uncertainty =  $\frac{0.01}{0.12} \times 100\% = 8.3\%$

For individual mass measurements, it is assumed there is no uncertainty in the tare of the balance.

## Multiple measurements

Where quantities are measured by difference, there will be an uncertainty in each measurement, which must be combined to give the uncertainty in the final value. The principle of the following example for a mass measurement can be applied to other quantities measured by difference, such as temperature difference and titre.

For two mass measurements that give a resultant mass by difference, there are two uncertainties. These uncertainties are combined to give the uncertainty in the resultant mass. The formula for the percentage uncertainty is then:

$$\text{percentage uncertainty} = \frac{2 \times \text{uncertainty in each measurement}}{\text{quantity measured}} \times 100\%$$

For example, using the same two-decimal place balance as above:

Mass of simple mass potometer on day 1 = 23.45 g uncertainty = 0.01 g

Mass of simple mass potometer on day 2 = 23.21 g uncertainty = 0.01 g

Mass lost = 0.23 g

overall uncertainty =  $2 \times 0.01$  g

There is a negligible percentage uncertainty in each mass measurement, but the overall percentage uncertainty in the mass loss is much greater:

$$\text{percentage uncertainty in mass loss} = \frac{2 \times 0.01}{0.23} \times 100\% = 8.7\%$$

## Notes

We are aware that some textbooks available do not give a consistent message regarding the treatment of uncertainties. In OCR Biology A and B we will therefore allow both half the smallest division as the absolute uncertainty for a measuring instrument and the smallest division itself as the absolute uncertainty. This will ensure that we do not penalise students in any examination - since this ambiguity is not their fault.

The guidance on electronic instruments differs from guidance previously provided by OCR and other sources which state that the uncertainty for digital apparatus is half the resolution, e.g.  $\pm 0.005$  g for a two-decimal place balance. The guidance here has been updated for consistency across the OCR suite of A level sciences. For assessment purposes, approaches correctly using either the resolution or half the resolution as the uncertainty will be considered acceptable.

## Recording measurements

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When using a digital measuring device (such as a modern top pan balance or ammeter),

- record *all* the digits shown. (Note: when using a digital timer such as a stopwatch, do not record to more than two decimal places.)

When using a non-digital device (such as a ruler or a burette),

- record all the figures that are known for certain plus one that is estimated.

## Consistency of presentation of raw data

All raw readings of a particular quantity should be recorded to the same number of decimal places. These should be consistent with the apparatus used to make the measurement (see above).

## Presentation of results

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### Table headings

It is expected that **all** table column (or row) headings will consist of a quantity **and** a unit. The quantity may be represented by a symbol or written in words. There must be some kind of distinguishing notation between the quantity and the unit. Students should be encouraged to use solidus notation, but a variety of other notations are accepted. For example:

$$T / ^\circ\text{C} \quad T (^{\circ}\text{C}) \quad T \text{ in } ^\circ\text{C} \quad \frac{T}{^{\circ}\text{C}} \quad \text{are all } \mathbf{acceptable} \text{ as column headings.}$$

Students should avoid notations that do not distinguish between the quantity and the unit, such as

$$T \text{ cm} \quad T_{\text{cm}} \quad \text{just 'cm'}$$

The logarithm of a quantity has no units. Therefore, the heading for e.g. pH measurements can be written simply as 'pH'.

## Significant figures

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### How many significant figures should be used?

The result of a calculation that involves measured quantities cannot be more certain than the *least* certain of the information that is used. So the result should contain the same number of significant figures as the measurement that has the *smallest* number of significant figures. A common mistake by students is to simply copy down the final answer from the display of a calculator. This often has far more significant figures than the measurements justify.

### Rounding off

When rounding off a number that has more significant figures than are justified (as in the example above), if the last figure is between 5 and 9 inclusive round up; if it is between 0 and 4 inclusive round down. For example, the number 3.5099 rounded to:

4 sig. figs is 3.510      3 sig. figs is 3.51      2 sig. figs is 3.5      1 sig. fig is 4

### How do we know the number of significant figures?

If the number 450.13 is rounded to 2 sig. figs or 3 sig. figs, the result is 450. Therefore, if seen in isolation, it would be impossible to know whether the final zero in 450 is significant (and the value to 3 sig. figs) or insignificant (and the value to 2 sig. figs). In such cases, standard form should be used and is unambiguous:

- $4.5 \times 10^2$  is to 2 sig. figs
- $4.50 \times 10^2$  is to 3 sig. figs.

### When to round off

It is important to be careful when rounding off in a calculation with two or more steps.

- Rounding off should be left until the very end of the calculation.
- Rounding off after each step, and using this rounded figure as the starting figure for the next step, is likely to make a difference to the final answer. This introduces a **rounding error**. *Students often introduce rounding errors in multi-step calculations.*

## Errors in procedure

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The accuracy of a final result also depends on the procedure used. Errors can be introduced through a poorly planned, or implemented, method or a mis-calibrated instrument.

### Anomalies (outliers)

Anomalies (outliers) are values in a set of results that are judged not to be part of the inherent variation. If a piece of data was produced due to a failure in the experimental procedure, or by human error, it would be justifiable to remove it before analysing the data. For example, if the volume of product recorded for an enzyme reaction is clearly different to the other readings taken for that particular data point, it might be judged as being an outlier and could be ignored when the mean volume is calculated. However, data must never be discarded simply because it does not correspond with expectation.

## Appendix 4: Units

Within the OCR GCE Biology qualifications, students will in general be expected to use and recognise standard SI units. For example,  $\text{dm}^3$  is used rather than *l* (litre). However, there are exceptions to this, e.g. degree ( $^\circ$ ) for angles, which is used in preference to the radian, minutes (min) and hours (h) in addition to seconds (s), *ml* and  $\mu\text{l}$  in pipette use (as discussed below). In general, any other conversion to or from non-standard units that may be required in assessment would be provided in the question.

moles of substance	mol
area	$\text{m}^2$ , $\text{cm}^2$ or $\text{mm}^2$
concentration	$\text{mol dm}^{-3}$ or $\text{g dm}^{-3}$ <i>OCR specifications do not support the use of M (molar)</i>
energy	J
heart rate	bpm
length	m, cm, mm or $\mu\text{m}$
light intensity	lux
mass	g
microbiological titre	CFU (colony forming units), PFU (plaque forming units)
pH	<i>no units</i>
potential difference	V
temperature	$^\circ\text{C}$
time	s <i>(but, as noted above, min or h will often be appropriate and students should also recognise ms)</i>
volume	$\text{cm}^3$ or $\text{dm}^3$ <i>Measurements using laboratory apparatus will commonly be in <math>\text{cm}^3</math>, while concentrations are expressed in terms of <math>\text{dm}^3</math>. <math>\text{ml}</math> and <math>\text{l}</math> are not official SI units. However, biology students should be familiar with <math>\mu\text{l}</math>, <math>\text{ml}</math> and <math>\text{l}</math> and be able to correctly equate these with <math>\text{mm}^3</math>, <math>\text{cm}^3</math> and <math>\text{dm}^3</math>. If the non-SI units have been used (for example many practical protocols refer to small volumes using <math>\text{ml}</math>) the conversion to the correct SI units should be made before the data is further processed.</i>

# Appendix 5: Tables and Graphs

## Tables

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The following guidelines should be followed when presenting results in tables.

- All raw data in a single table with ruled lines and border.
- Independent variable (IV) in the first column; dependent variable (DV) in columns to the right (for quantitative observations) OR descriptive comments in columns to the right (for qualitative observations).
- Processed data (e.g. means, rates, standard deviations) in columns to the far right.
- No calculations in the table, only calculated values.
- Each column headed with informative description (for qualitative data) or physical quantity **and** correct units (for quantitative data); units separated from physical quantity using either brackets or a solidus (slash).
- No units in the body of the table, only in the column headings.
- Raw data recorded to a number of decimal places appropriate to the resolution of the measuring equipment.
- All raw data of the same type recorded to the same number of decimal places.
- Processed data recorded to up to one significant figure more than the raw data.

## Graphs

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The following general guidelines should be followed when presenting data in graphs.

- The type of graph used (e.g. bar chart, histogram or scattergram or line graph) should be appropriate to the data collected.
- The graph should be of an appropriate size to make good use of the paper.
- There should be an informative title.
- Error bars are plotted by the addition and subtraction of one standard deviation.
- Range bars show the highest and lowest readings for each set of data.

### Bar charts

- Bar charts are used when the independent variable is non-numerical, e.g. the names of different insect species found on trees. These data are discontinuous.
- They can be made up of lines, or blocks of equal width, which do not touch.
- The lines or blocks can be arranged in any order, but it can aid comparison if they are arranged in descending order of size.
- Each axis should be labelled clearly with an appropriate scale.

## Histograms

- These are used when the independent variable is numerical and the data are continuous.
- They are sometimes referred to as frequency diagrams.
- One axis, usually the x-axis, represents the independent variable and is continuous. It should be labelled clearly with an appropriate scale.
- The number of classes needs to be established. This will largely depend on the type and nature of the data. However, five times the log of the number of observations is one approach.
- The blocks should be drawn touching.
- The edges of the blocks should be labelled, so a block might be labelled '7' at the left and '8' at the right; this is expressed as a class range 7 - 8 units but it is implied that 7.0 is included in this range but 8.0 is not. 8.0 will be included in the next class range, 8 - 9.
- The other axis, conventionally the y-axis, represents the number or frequency, and should be labelled with an appropriate scale.

## Scattergrams

These are used when investigating the relationship between two naturally changing (rather than experimentally manipulated) variables. The data can then be used to establish if there is a relationship between the variables. The relationship can be a positive correlation, a negative correlation or no correlation at all.

- The two axes of the graph are marked out with appropriate scales.
- The two variables are plotted for each sample as a point so that each point on the graph represents an individual.

## Line graphs

These are used to show the relationship between an independent variable (usually manipulated by the investigator but there are exceptions, most commonly time) and a dependent variable measured during the investigation.

- The independent variable should be plotted on the horizontal axis (x) and the dependent variable plotted on the vertical axis (y).
- Axis labels should be stated horizontally and in lower case, using SI units.
- Axes should have an arrow end when there is no scale.
- If a graph shows more than one curve, then each curve should be labelled to show what it represents.

This appendix provides information on the following graphical skills relating to line graphs:

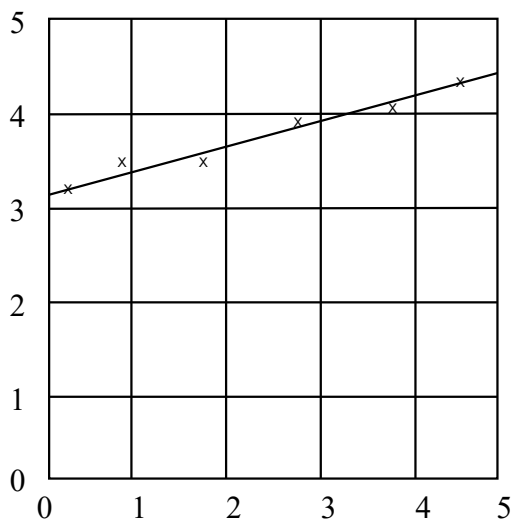
- choice of scale
- plotting of points
- line of best fit
- calculation of gradient
- determination of the y-intercept.

This relates to skills assessed in written examinations and the Practical Endorsement.

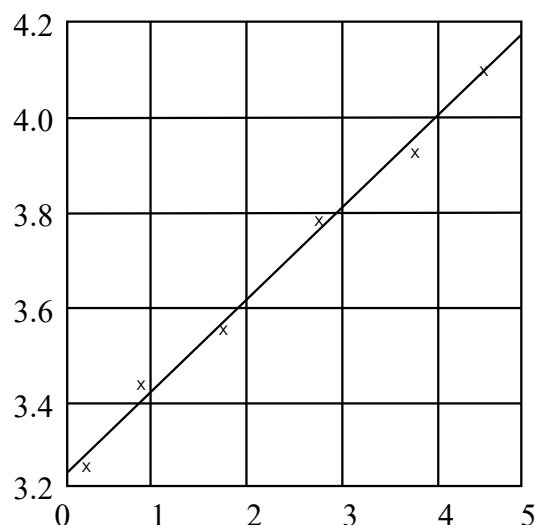


## Choice of scales

Scales should be chosen so that the plotted points occupy at least half the graph grid in both the x and y directions.



Not acceptable - scale in the y-direction is compressed



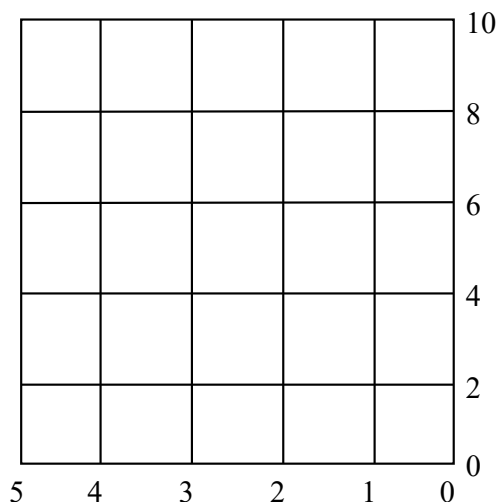
Acceptable - points fill more than half the graph grid in both the x and y directions

It is expected that each axis will be labelled with the quantity (including unit) which is being plotted. The quantity may be represented by a symbol or written in words. There must be some kind of distinguishing notation between the quantity and the unit, e.g. brackets or a solidus.

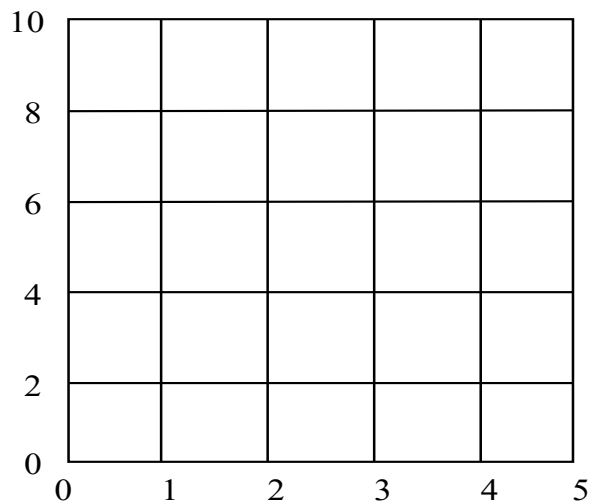
$T / ^\circ\text{C}$      $T(^{\circ}\text{C})$      $T \text{ in } ^\circ\text{C}$      $\frac{T}{^{\circ}\text{C}}$  are all **acceptable** as axis labels.

Note: pH has no units so the axis label for pH measurements can be written simply as 'pH'.

The scale direction must be conventional (i.e. increasing from left to right).



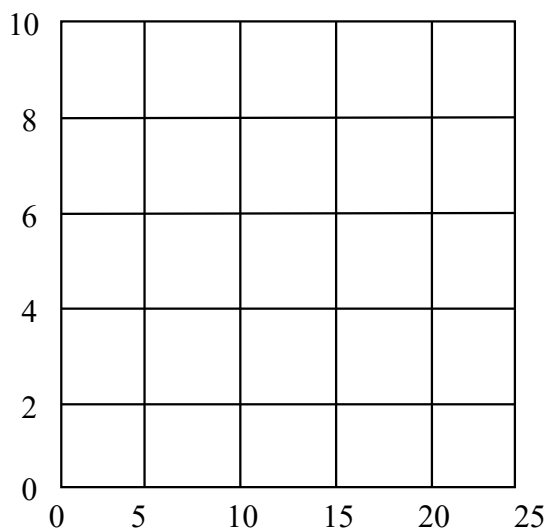
Not acceptable - unconventional scale direction



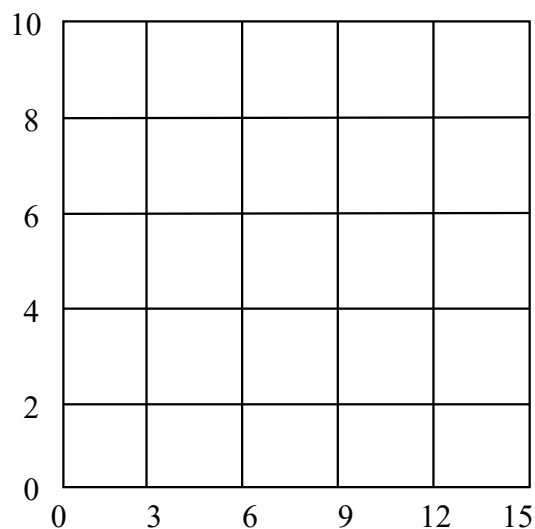
Acceptable - conventional scale direction

This problem often occurs when scales are used with negative numbers.

Students should be encouraged to choose scales that are easy to work with.



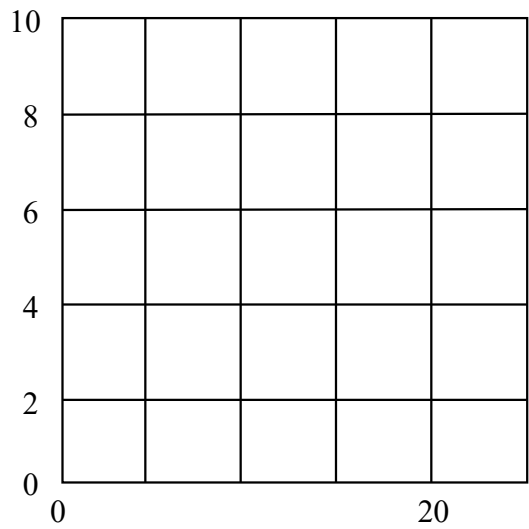
Acceptable scale divisions.



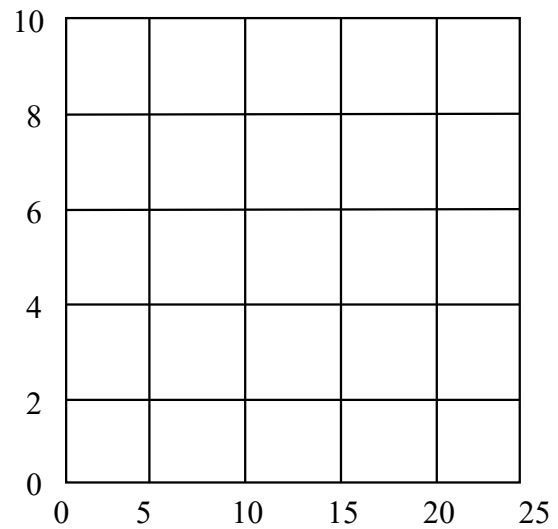
Not acceptable - awkward scale on the x-axis.

Students who choose awkward scales in examinations often lose marks for plotting points (as they cannot read the scales correctly) and calculation of gradient ( $\Delta x$  and  $\Delta y$  often misread – again because of poor choice of scale).

Scales should be labelled reasonably frequently (i.e. there should not be more than three large squares between each scale label on either axis).

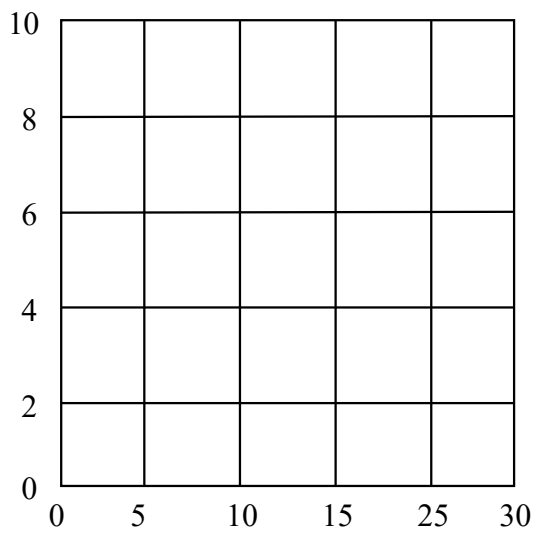


Not acceptable - too many large squares with no label

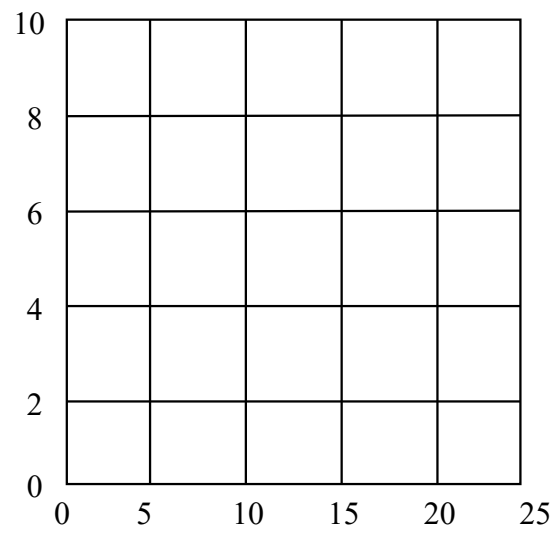


Acceptable - scales have regular labels

There should be no 'holes' in the scale.



Not acceptable - non-linear scale on the x-axis

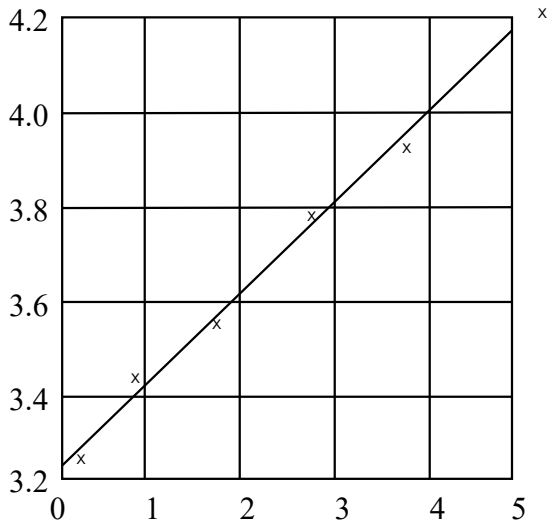


Acceptable - scale labelling is regular

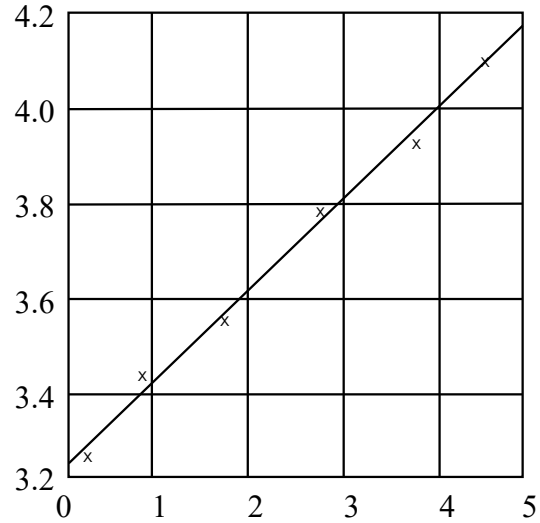
## Plotting of points

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Plots in the margin area are not allowed, and will be ignored in examinations. Sometimes students (realising they have made a poor choice of scale) will attempt to draw a series of lines in the margin area so that they can plot the 'extra' point in the margin area. This is considered to be bad practice and would not be credited.



Not acceptable - the last point has been plotted in the margin area



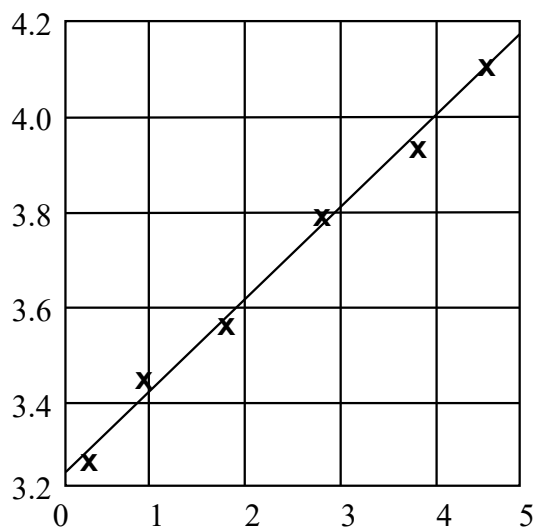
Acceptable - all plotted points are on the graph grid

It is expected that all observations will be plotted (e.g. if six observations have been made then it is expected that there will be six plots).

Plotted points must be accurate to half a small square.

Plots must be clear (and not obscured by the line of best fit or other working).

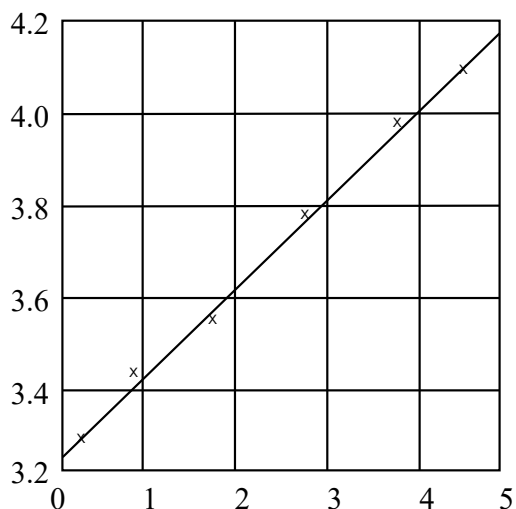
Thick plots are not acceptable. If it cannot be judged whether a plot is accurate to half a small square (because the plot is too thick) then the plotting mark will not be awarded.



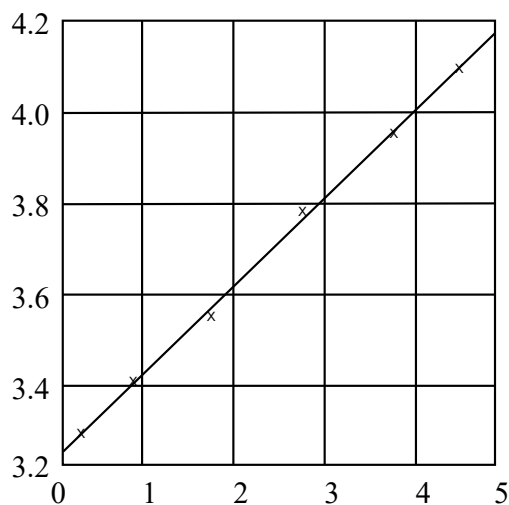
Thick plots not acceptable

## Line (or curve) of best fit

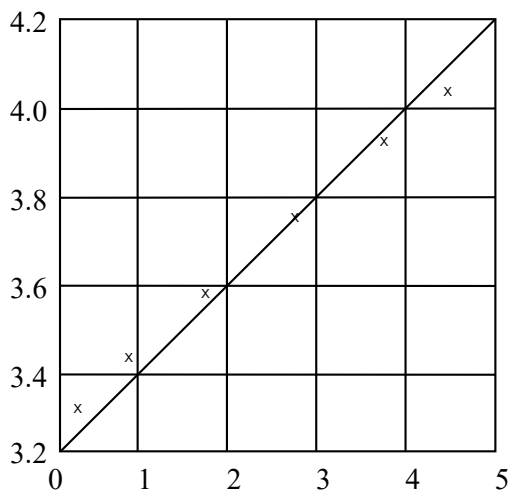
There must be a reasonable balance of points about the line. Students use a clear plastic rule so that points can be seen which are on both sides of the line as it is being drawn.



Not acceptable - too many points above the line



Acceptable balance of points about the line

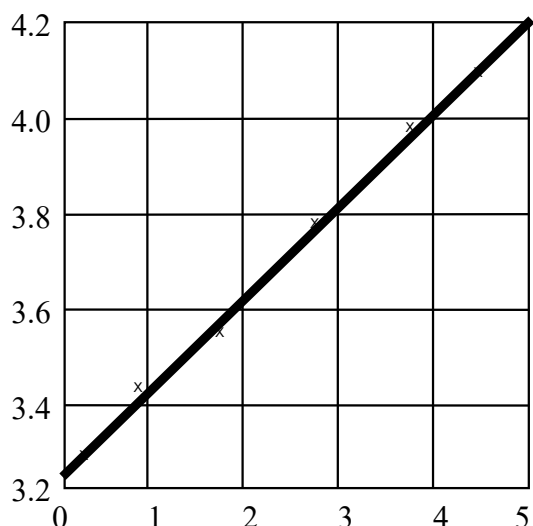


Not acceptable - forced line through the origin (not appropriate in this instance)

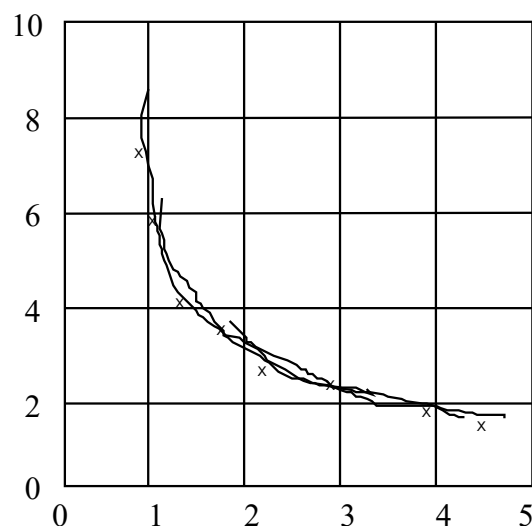
### Extrapolation

Extrapolation of a line of best fit can be done where appropriate. For example it might be necessary to extrapolate back to discover the intercept with the y axis. Where the purpose of the graph is to present the data within the experimental range only (with the possibility for deriving predicted values through interpolation) no extrapolation is needed and the line should be confined to the range of the independent variable. This unifies practice across the three sciences: Chemistry, Physics and Biology.

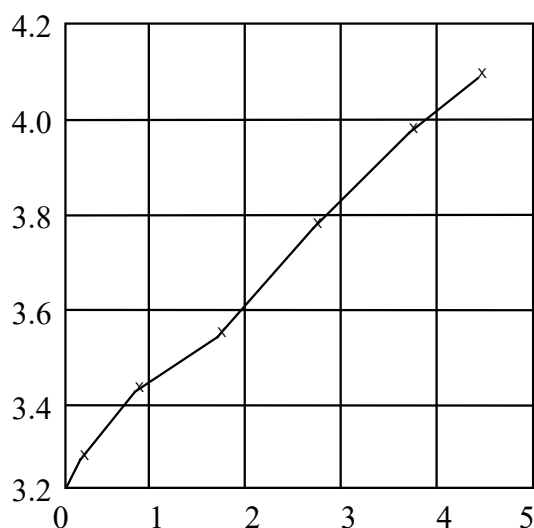
The line must be thin and clear. Thick/hairy/point-to-point/kinked lines are not credited.



Not acceptable - thick line



Not acceptable - 'hairy' curve



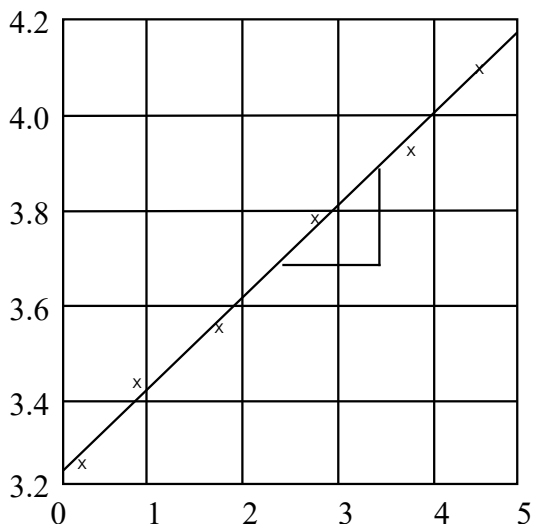
Not acceptable – joining point-to-point even though a clear trend exists.

Note: In the previous OCR AS/A2 Biology specification (H021/H421) the guidance for line graphs stated that 'straight lines should join points'. For the OCR AS and A Level Biology current qualifications (H020/H420, H022/H422) the guidance has changed. If a trend can be identified a line (or curve) of best fit should be drawn as described above. If no trend can be identified, or if the nature of the data means interpolation between data points is not appropriate, straight lines can be used to join points if this increases the clarity of presentation. This unifies practice across the three sciences: Chemistry, Physics and Biology.

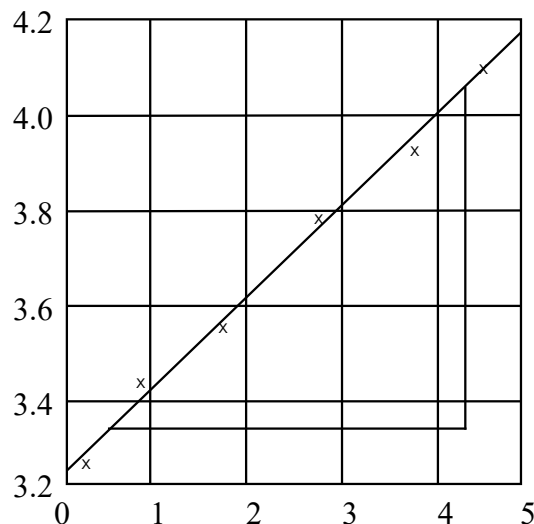
## Determining gradients

All the working must be shown. A 'bald' value for the gradient may not be credited. It is helpful to both students and examiners if the triangle used to find the gradient is drawn on the graph grid and the co-ordinates of the vertices clearly labelled.

The length of the hypotenuse of the triangle should be greater than half the length of the line which has been drawn.



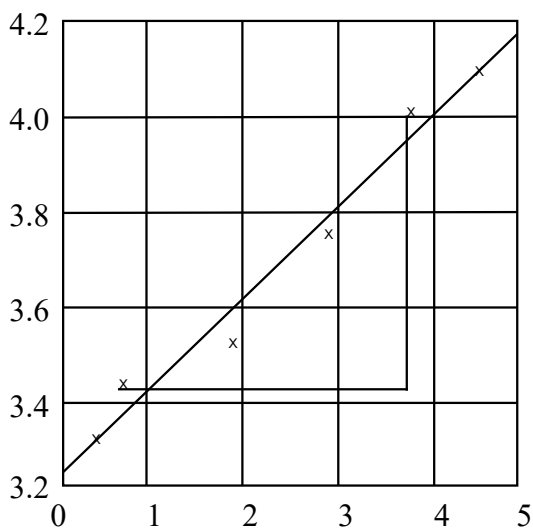
Not acceptable - the 'triangle' used is too small



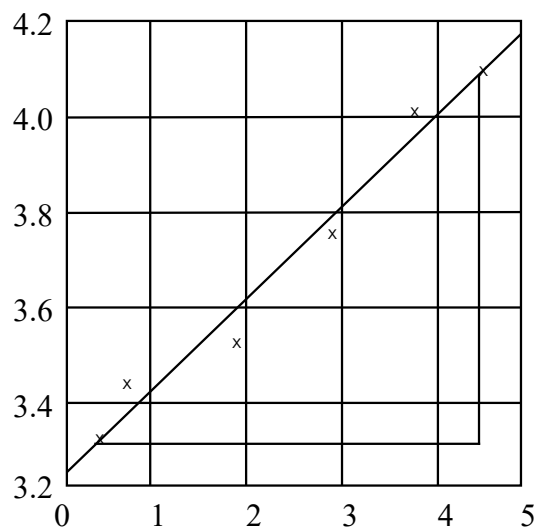
Acceptable – a large 'triangle' used

The values of  $\Delta x$  and  $\Delta y$  must be given to an accuracy of at least one small square (i.e. the 'read-off' values must be accurate to half a small square).

If plots are used which have been taken from the table of results then they must lie on the line of best fit (to within half a small square).



Not acceptable - the data points used which do not lie on the line of best fit

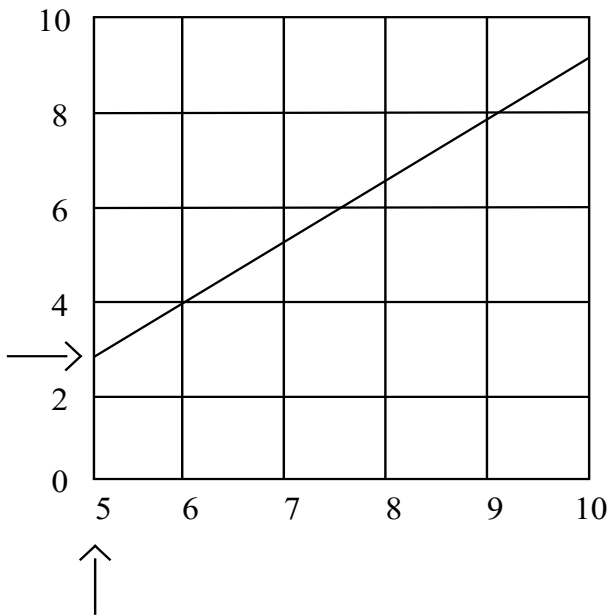


Acceptable - plots on line

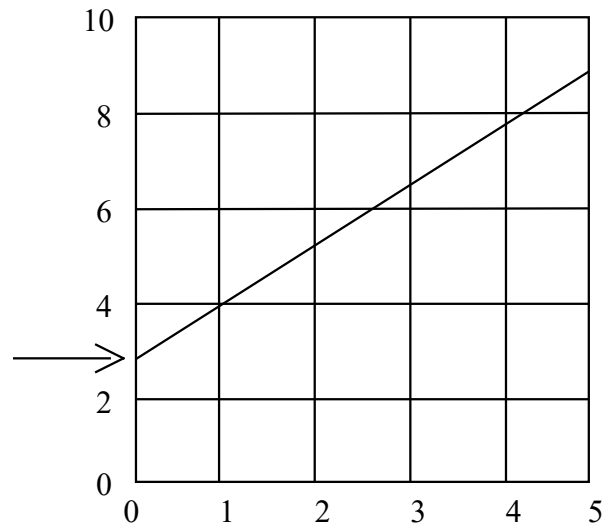
Students should remember to use appropriate units when reporting gradient values.

## Intercept

The y-intercept must be read from an axis where  $x = 0$ . It is often the case that students will choose scales so that the plotted points fill the graph grid (as they should do) but then go on to read the y-intercept from a line other than  $x = 0$ .



Not acceptable – the y-intercept is found from the line  $x = 5$



Acceptable – the value taken from the line  $x = 0$

Alternatively, the intercept value can be calculated, recognising that a straight-line graph has the basic formula  $y = mx + c$ . Substituting the gradient value and a set of coordinates on the line of best fit and solving the equation will give the intercept.



# Appendix 6: Referencing

One of the requirements of the Practical Endorsement is that students demonstrate that they can appropriately cite sources of information. The point of referencing is to provide the sources of information that have been used to produce the document, and to enable readers to find that information. There are many different systems of reference in use; the most important thing for students to appreciate at this level is that they should be consistent in how they reference, and that they provide sufficient information for the reader to find the source.

## Systems of citation

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Wherever a piece of information that has been retrieved from a source is provided in a text, an in-text citation should be included that links to the full original source in the reference list.

Use of a specific referencing system for the Practical Endorsement is not expected. However, students' referencing should be complete and consistent and allowing you to accurately find the original source. If students are already using a particular referencing system in another area of study, for example for an Extended Project qualification, it would make sense if they use the same system within their Biology studies.

There are two main systems of in-text citation: the Vancouver system, which uses numerical citations, and the parenthetical system (of which the Harvard system is the best known version), in which limited reference information is given in brackets in the text.

Students are likely to find the Harvard system easier to handle. However, students should be aware of the Vancouver system as they may come across this system in their secondary research.

### Vancouver system

The Vancouver system looks like this:

The density of viable bacteria in a culture can be estimated by creating serial dilutions, plating out and counting colonies.<sup>1</sup>

The full references are given in a numbered list at the end of the document, with each number linked to the appropriate reference, e.g.:

1. Bloggs, J. (2011) *Microbiology*, 2nd ed., Cambridge, Practical Biology Publications

The references are ordered in the sequence in which they are first cited in the text. The numbers are repeated in the in-text citations as required, so the same number is always used to cite a given reference.

### Parenthetical (Harvard) system

The parenthetical system looks like this:

The density of viable bacteria in a culture can be estimated by creating serial dilutions, plating out and counting colonies (Bloggs, 2011).

The author(s) and date of the work are included in brackets at the appropriate point in the text. In this case, the list of full references at the end of the document is ordered alphabetically, and the references are not numbered.

For multi-author works, the full list of names is usually not given in in-text references. Rather, the first name is given followed by 'et al.'. This is commonly done for works with more than three authors.

## References

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While different referencing systems have minor variations in how they present complete references, the basic information provided is always very similar, and based on the principle of providing sufficient information so that the reader can find the information source.

An overview is given below of standard referencing formats for the types of sources that students are likely to cite.

### Books

General reference format:

Authors (year), *Title*, edition (if relevant), publisher's location, publisher

For example:

Roberts, M.B.V. (1986), *Biology – A Functional Approach*, 4<sup>th</sup> ed., Cheltenham, Nelson Thornes

For books that have an editor or editors, include (ed.) or (eds) after the names.

If a book does not have named authors or editors, the reference begins with the title, e.g.:

*CLEAPSS Laboratory Handbook* (2001), Uxbridge, CLEAPSS School Science Service

### Journal articles

General reference format:

Authors (year), 'Article title', *Journal title*, vol. no, issue no, pp. xxx–xxx

For example:

Meredith, Jr, J. E., Fazeli, B., Schwartz, M. A. (1993), 'The extracellular matrix as a cell survival factor', *Mol. Biol. Cell*, vol. 4, no 9, pp. 953–961

### Websites

General reference format:

Authors (year), *Title*. [online] Last accessed date: URL

For example:

Goldacre, B. (2010), *The stigma gene*. [online] Last accessed 4 April 2015:  
<http://www.badscience.net/2010/10/pride-and-prejudice/>

Webpages and online resources frequently do not have individual authors. In that case, the name of the organisation is given.

Nuffield Foundation (2011), *Maintaining and preparing cultures of bacteria and yeasts*. [online] Last accessed 28 February 2015: <http://www.nuffieldfoundation.org/practical-biology/maintaining-and-preparing-cultures-bacteria-and-yeasts>

Similarly, it is often not possible to find the year in which online material or documents were produced. In that case, use the year in which the information was sourced.

If no author or organisation can be found, reference the website by title. However, in that case due consideration should be given as to whether the website is a trustworthy source!

# Appendix 7: Resources

## General resources

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There are many resources available to help teachers provide support to students. These include both books and websites.

### Useful websites are:

- CLEAPSS at [www.cleapss.org.uk](http://www.cleapss.org.uk)
- Royal Society of Biology at [www.rsb.org.uk/](http://www.rsb.org.uk/)
- The Nuffield Foundation Practical Biology pages at <http://www.nuffieldfoundation.org/practical-biology>
- ASE at [www.schoolscience.co.uk](http://www.schoolscience.co.uk)
- Science and Plants for Schools at [www.saps.org.uk](http://www.saps.org.uk)
- Microbiology Society <https://microbiologysociety.org/>
- Wellcome Trust <https://wellcome.org/>
- Field Studies Council <http://www.biology-fieldwork.org/>
- British Ecological Society <https://www.britishecologicalsociety.org/learning-and-resources/learning-resources/>
- Biochemical Society <https://www.biochemistry.org/careers-and-education/education/>

### Useful books:

- Meatyard, B. (ed.) (2009) *Biological Nomenclature* 4th ed., London, Institute of Biology
- Swinfen, T. C. (ed.) (2000) *Signs, Symbols and Systematics*, Hatfield, The Association for Science Education
- Campbell, P. (ed.) (2010) *The Language of Measurement – Terminology used in school science investigations*, Hatfield, The Association for Science Education

## Professional Development

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OCR runs professional development courses every year, and these include sessions to support the Practical Endorsement. More details about professional development provision are available at <https://teachcambridge.org/>.

## Subject advisor Support

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OCR Subject advisors are available to offer support and guidance on all aspects of the Practical Endorsement. Direct queries regarding the Practical Endorsement to the OCR Science Team through: [science@ocr.org.uk](mailto:science@ocr.org.uk)

## Need to get in touch?

If you ever have any questions about OCR qualifications or services (including administration, logistics and teaching) please feel free to get in touch with our customer support centre.

Call us on  
**01223 553998**

Alternatively, you can email us on  
**support@ocr.org.uk**

For more information visit

 **ocr.org.uk/qualifications/resource-finder**

 **ocr.org.uk**

 **facebook.com/ocrextams**

 **twitter.com/ocrextams**

 **instagram.com/ocrextaminations**

 **linkedin.com/company/ocr**

 **youtube.com/ocrextams**

## We really value your feedback

Click to send us an autogenerated email about this resource. Add comments if you want to. Let us know how we can improve this resource or what else you need. Your email address will not be used or shared for any marketing purposes.



**I like this**



**I dislike this**

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