STUDENT GUIDE

With exam-style questions and model answers

PEARSON EDEXCEL A-LEVEL

# Practical Biology A

## (Salters–Nuffield)

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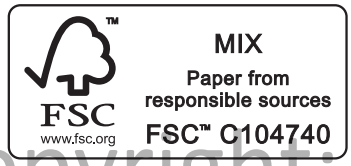

# Skills Guidance

## Practical advice

### Following instructions

When carrying out practical work you usually follow a set of written instructions. Before you start the practical work read them through to the end. Annotate the instructions to help you understand them. Then check that you have all the apparatus and materials listed. When you are ready to start read the first instruction carefully and carry it out. Put a tick by each instruction when you have completed it. Proceed carefully through the rest of the instructions, double-checking that you are sticking to them. This is important not only to ensure the collection of accurate data but also that the practical activity is safe. Following instructions shows competency in CPAC 1a.

### Safety

Carrying out practical work safely is absolutely essential. If you work unsafely you are putting other people in the class at risk, as well as yourself. Safe working demonstrates competency in CPAC 3a and 3b. Below is some general safety advice, but if you are unsure whether something is safe you must ask your teacher before carrying it out.

- Keep your work area well organised and tidy.
- Use one area for wet work and keep another area dry for writing in your notes/lab book. Do your practical work over the bench, not over your papers.
- Wear protective goggles/spectacles.
- Make sure that you are familiar with hazard warning symbols and know how to respond to them.
- Take special care when using knives, scalpels, glassware, chemicals, Bunsen flames, hot water etc.
- Inform the teacher or technician immediately if you have an accident.
- Clear up any spillages immediately.

Table 1 shows examples of poor laboratory practice that teachers will use as reasons for not awarding you the relevant competency. It also shows equivalent good practice.

**Practical tip**

Your teacher will assess your approach to working methodically and safely while you carry out your practical work.

**Table 1** Examples of poor and good laboratory practice

| Poor practice | Good practice |
|---|---|
| Using incorrect apparatus or equipment without realising*, for example using a 10 $cm^3$ syringe instead of a 1 $cm^3$ one to dispense 0.5 $cm^3$ of a liquid | Choosing the correct apparatus/equipment/chemicals from those provided so that the correct results are obtained |
| Using the same syringe to dispense different liquids without realising*, so that contamination occurs | Using separate syringes when necessary and keeping syringes separate once used (for correct reuse) or washing out a syringe between uses to dispense different solutions |

| Poor practice | Good practice |
|---|---|
| Cutting slices or cubes or sections carelessly so that sections are of uneven thickness or cubes are of unequal size | Using cutting equipment (e.g. scalpels and knives) and measuring equipment (e.g. rulers) with care to produce slices and cubes of correct sizes |
| Allowing fluids to drip off the outside of beakers/tubing/stirring rods/tissue samples into other solutions so that there is the risk of cross-contamination | Rinsing and drying equipment when necessary; clearing off spills on the outside of beakers; keeping different items in clearly defined areas on the bench |
| Haphazard use of the stop clock/bench timer so that incorrect times are recorded; samples are not taken at correct time intervals | Checking how to use the stop clock/bench timer before starting; careful checking of times; resetting back to zero when required |
| Filtering suspensions through a filter funnel where the filter paper has not been folded correctly/has a tear/has not been fitted into the funnel correctly | Folding a piece of filter paper and then opening it out into the filter funnel; filtering suspensions so that a clear solution, the filtrate, runs through and the precipitate/larger insoluble particles remain on the filter paper |
| *Realising a mistake and asking for fresh syringes is considered good practice. | |

## Planning investigations

In the exam papers you may be asked to plan some aspect of an investigation. Obviously you are not going to carry it out, but you should write your answer as if you were. Also you will probably plan and carry out a complete investigation as part of your practical work so that you can be assessed on your skills at researching and writing a scientific report.

Throughout your course and in the exams you will be tested on the skills involved in planning, such as identifying variables, stating a hypothesis, writing a method and explaining how to collect results and/or analyse them. Writing full plans during your course will prepare you well for these questions. Here are some steps to follow while planning an investigation.

1. **Identify a question to answer and write a hypothesis**. Read the information provided carefully and look for clues. Write a question that you have to answer by experiment and then write a hypothesis, which is a clear statement about what you think will happen. You must write a **testable hypothesis** — one that you can test by experiment.
2. **Carry out some research**. Use sources of information to read about the problem you are trying to solve. Look for ideas for the strategy you will plan and decide how results could be analysed statistically.
3. **Write a null hypothesis**. If you are going to use a statistical test to analyse your results then you must rewrite your hypothesis as a negative statement, known as a **null hypothesis**. This states the opposite of your hypothesis. Your experiment must test the idea that there will be *no effect*.
4. **Identify the independent, dependent and control variables for the investigation:**
   - The **independent variable** (IV) is the one that you choose to change (or are told to change) in an investigation. In some investigations there are two or more IVs.
   - The **dependent variable** (DV) is the variable that you do not know at the beginning; it is the variable that you set out to observe and/or measure.
   - **Control variables** (CV) are those that are kept constant because they might have an impact on the values of the DV.

**Practical tip**

Syringes should be washed out with water and then with a small volume of the liquid you are going to dispense.

5 **Decide on a strategy for your experiment**. This is a brief outline of a method that tests your hypothesis.

6 **Choose apparatus and materials that are appropriate**. You should choose only apparatus that is available in a school or college lab, not sophisticated apparatus, such as electron microscopes or DNA sequencing machines, that are not. Often it is a good idea to justify your choice of the main items of apparatus.

7 **Expand the strategy into a detailed procedure, using numbered steps**. Avoid using continuous prose because it is easier to follow a series of instructions. Notice that numbered points allow you to include instructions, such as 'repeat step 6'. The procedure must describe how results are to be collected.

8 **Explain how results are to be presented**. A good way to do this is to write an outline of a table with columns and rows headed up in full, with units.

9 **Explain how results are to be analysed.** This includes:
- any data processing
- the type or types of graph (if any)
- the appropriate statistical test

10 **Plan and carry out a pilot investigation** to trial your ideas. You may have to modify your strategy and/or your detailed plan as a result. If so, record all the details and include them in your report.

**Practical tip**

If you choose to use a colorimeter, you could say that this gives quantitative results that are easier for others to reproduce than if you use colour standards (charts showing expected colours). You will use a colorimeter in core practical 1.

## Evaluating procedures

When carrying out an experimental procedure it is important to consider the way in which the procedure was carried out and the quality of the data collected. You need to ask yourself the question: 'can I have confidence in my data?' If you do not have confidence in the data then you cannot have confidence in the conclusion(s) that you make.

There are quite a few terms with specific meanings that are used when discussing the quality of the procedure and the results obtained:

- **Resolution** is the smallest change in quantity that can be measured with the apparatus that you are using. This refers both to the apparatus used to measure out quantities as part of the procedure and the apparatus used to collect results. It refers to the number of significant figures (or decimal places) in readings.
- **Precision** is a measure of the closeness of agreement between individual results obtained using the same procedure under exactly the same conditions. However, closeness of replicates does not mean that the data are close to the true value.
- **Repeatable results** are replicate results that are in close agreement. You can use mathematical methods to help evaluate the variation in replicate results.
- **Reproducible results** are results that are produced by someone else who follows exactly the same procedure using the same apparatus and materials, but in a different place and at a different time. You can only comment on this in response to a question if you are given results from different people.

**Practical tip**

Notice that resolution also applies to microscopy. It refers to the smallest distance that can be detected when using a microscope.

- **Accuracy** is a measure of the closeness of agreement between individual results or a set of results and an accepted 'true' value. In biology it is often difficult to know the true value in an investigation. There will usually be a true value, but errors and limitations reduce the chances that results are close to that true value and therefore accurate.

The first thing to do when evaluating is to consider the procedure that you followed. Is it possible that there were any **measurement errors** in the method? There are two types of error:

- **Systematic errors** are always the same throughout the investigation. A common type of systematic error is when the measuring device gives readings that are incorrect by a certain value. It could be that one of the controlled variables is always incorrect by the same quantity. If there are small systematic errors (that are always the same) then the data may be precise, but not accurate. The effect of these errors is to overestimate or underestimate the true values of the dependent variable.
- **Random errors** occur when you do not carry out the procedure in exactly the same way each time. You may also read the apparatus in a slightly different way each time you take a reading. These errors affect some of the results, but not all of them. They do not always affect the results in the same way. Random errors could also be the result of the variation in biological material.

Do not think of errors as mistakes. Even in a perfectly performed investigation there will be errors. Systematic errors may not be easy to identify, but you should always check the accuracy of any measuring instruments, such as balances, colorimeters and pH meters. Random errors should show up in the data, making the data less reliable. However, random errors may affect one value of your independent variable, but not all of them (Figure 1).

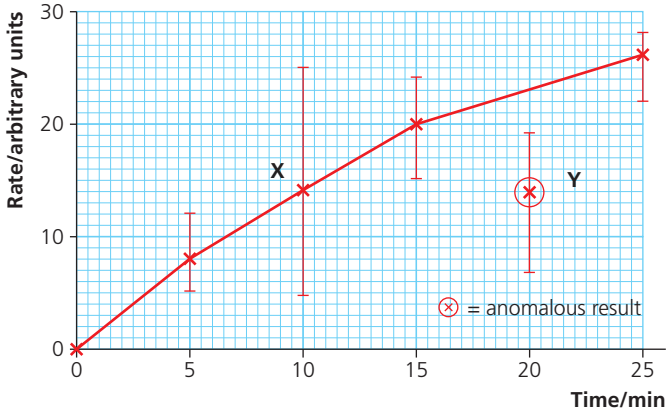


**Figure 1** The effect of random errors on processed data

The results plotted in Figure 1 are mean values with range bars. You can see that the result labelled X has a much wider range than the others. This suggests that there may have been one, or more, random errors in the readings for 10 minutes. The result labelled Y does not fit the overall trend of the other results. This may be because there were random errors when collecting all the data for 20 minutes.

**Practical tip**

Take special care over using the term accuracy. There are few biology investigations in which you can say what the 'true' value(s) should be.

**Practical tip**

The words in bold type are important key terms that you must understand and use. Write yourself a list with their definitions.

**Anomalous results** are results that do not fit the trend. They are sometimes known as outliers. An anomalous result can be:

- a replicate result that differs significantly from the others
- a result (which may or may not be a mean) for one value of the independent variable that does not fit the overall trend and is not included in the curve of best fit

You may be asked to suggest likely explanations for anomalous results. The anomaly could be the first result taken before the experimenter was confident in the procedure.

**Validity** refers to individual measurements and to the whole procedure. If you have a **valid result**, then you know that you measured what you set out to measure. If you have a **valid investigation** then you have measured what you intended to measure and you can be confident that the effect of changing the independent variable leads to changes in the dependent variable.

When you make a conclusion about an investigation then you can make a judgement about the extent to which the evidence collected supports that conclusion. In so doing you are expressing **confidence** in your conclusion. If asked to comment on the confidence in a conclusion then you should consider the following:

- the limitations in the procedure
- any uncontrolled variables
- the effects of errors (systematic and random) on the results
- the repeatability of the results
- the precision of the data collected
- the accuracy of the results

Give some positive aspects of the investigation first, followed by some criticisms. You should refer to specific aspects of the procedure and results, rather than using vague comments such as 'my conclusion is valid because my results are precise, reliable and accurate' — this is meaningless without supporting information. For example, you can say that your results are precise because you measured to two decimal places and that they are repeatable because the replicates are close together and there are no anomalous data. Your results may be accurate because they all agree with an expected trend. Always quote some examples of your raw or processed data in support of your arguments.

You should consider the variables involved in the investigation. Controlled variables are all the other variables that you were not investigating. Sometimes the instructions will tell you to keep these constant. In an investigation of enzyme-catalysed reactions, the temperature may be kept constant by placing the reaction mixtures in a thermostatically controlled water bath, for example at 20°C. The pH may also be controlled by using a buffer solution of, for example, pH 7.0. If variables are not controlled then they may influence the results; they are called **confounding variables** or **uncontrolled variables**. Sometimes, as in field studies, you may be aware of such variables and then 'take them into account' when analysing and interpreting results.

Controlled variables should not be confused with a **control experiment**. It is important to know that your results are valid — that they show what you think you are investigating.

## Repeatability and accuracy

In A-level practical tasks it is usual to carry out three repeats or replicates for each value of the independent variables if time and materials permit. These should be done separately from each other using exactly the same experimental procedures.

A balance used for weighing sections of potato tuber tissue might measure to the nearest 0.1 g. Some balances are more sensitive and weigh to the nearest 0.01 g. If measuring change in length you will use a ruler that measures to the nearest millimetre. These are measures of **resolution** in results taking. Recording to the nearest 0.1 g gives a higher resolution than measuring to the nearest 1 g. Similarly, measuring to the nearest millimetre gives a higher resolution than measuring to the nearest centimetre. So 10.6 g has a higher resolution than 11 g and a 13 mm measurement has a higher resolution than a 1 cm measurement. In this context resolution means the number of significant figures or decimal places to which values are expressed.

Stop clocks and bench timers can often measure to a hundredth of a second (0.01 s). It is highly unlikely that you could time a colour change or other event to this degree of resolution, so it is better to express your results to the nearest second (or even to the nearest 15 seconds or 30 seconds).

Resolution does not only involve results taking. It also involves the resolution of the apparatus that you use for preparing materials for practical tasks. For example, you may use a syringe for measuring out volumes. It is not easy to measure exactly with a syringe, especially with a coloured solution. It is possible to improve this by using a graduated pipette or a burette.

## Uncertainty in measuring

**Uncertainty** is half the smallest graduation on the apparatus — for example, if the smallest division on a syringe is 1.0 $cm^3$ then the uncertainty would be ±0.5 $cm^3$. So if you start measuring at 0 the uncertainty applies where you take the measurement — say at 6.3 $cm^3$. The result is expressed as 6.3 ± 0.5 $cm^3$. But if you have to start at a measurement other than 0 (for example when taking readings from a burette) the uncertainty applies at both ends, so it is multiplied by two as there is an error at each end, for example 7.5 ± 1.0 $cm^3$. The same applies to measuring a quantity in a syringe by sucking up from empty — the error would be half the minimum measurement. But when you take two readings from the syringe (say delivering 2.0 $cm^3$ by moving the plunger from 6.5 $cm^3$ to 4.5 $cm^3$) then the uncertainty is multiplied by two.

It is possible to calculate the **percentage error** for the apparatus you used for measuring your results. Imagine that you have collected a gas and measured the volume with a gas syringe that has graduations every 1 $cm^3$. If you have started from zero and measured 5 $cm^3$ of gas with your syringe, you can be certain that you have more than 4.5 $cm^3$ but less than 5.5 $cm^3$. Your error is ±0.5 $cm^3$ in 5 $cm^3$. This makes the percentage error:

$$\text{percentage error} = \frac{0.5}{5.0} \times 100 = 10\%$$

If the volume of gas collected was 10 $cm^3$, then the percentage error would be 5%.

**Practical tip**

Calculating a **running mean** is a good way to check that you have enough replicate results. Calculate the mean after you have collected each replicate and continue doing this until it remains near constant.

## Accurate data

It can be challenging to determine how accurate the data you collect in A-level practicals are. In biological investigations the true value is not always known. In some cases results can be checked with sources of data. For example, tidal volume readings should be about 500 $cm^3$. The water potential of the blood should be equivalent to 0.9% sodium chloride solution (–3.86 MPa). But the water potential of plant tissues varies considerably and there is no specific value against which results can be checked.

This is why it is important to evaluate the procedure followed in an investigation and evaluate the results obtained. Results are often considered to be anomalous and you need to think about how these might have been obtained. However, what might seem to be anomalies or outliers are not necessarily so.

## Recording observations and results in tables

In most of your practical work you will need to record results and observations. In almost all cases, results and observations will be recorded in tables.

Before you start to draw a table, decide what you wish to record. Decide on how many columns and how many rows you will need, and make a rough table in pencil. Make sure that you have read all the practical instructions before you draw the table outline. Follow these rules:

- Use plenty of space — do not make the table too small.
- Leave some space to the right of the table in case you suddenly decide you need to add more columns.
- Make the table ready to take observations and/or readings so that you can write them directly into the table rather than writing them on another page and then copying them into the table. Tables should show all the raw data you collect.
- Use a pencil and ruler to draw lines between the columns and between the rows. Rule lines around the whole table.
- Write a brief, but informative, heading for each column.
- The headings of the columns and rows that record measurements must include the relevant units. Write pure numbers in the body of the table without any units.
- When two or more columns are used to present data, the first column should be the independent variable; the second and subsequent columns should contain the dependent variables.
- If you have collected replicate results then they should all be shown.
- Entries in the body of the table should be brief — they should be single words, short descriptive phrases, numbers, ticks or crosses.
- Data should be ordered so that trends and patterns can be seen — it is best to arrange the values of the independent variable in ascending order.
- Tables should be given informative headings.
- Units are separated from the description of the variable by a forward slash (/) or by putting the units into brackets. The slash should *not* be used to mean 'per' in compound units. For example, if you include concentrations, do *not* write mol per $dm^3$ as mol/$dm^3$. It should be written as mol $dm^{-3}$.

**Practical tip**

There are plenty of examples in this guide to help you become proficient in drawing and completing tables of results.

**Practical tip**

Sometimes it may be necessary to draw the table in landscape, especially if you are collecting a lot of raw data.