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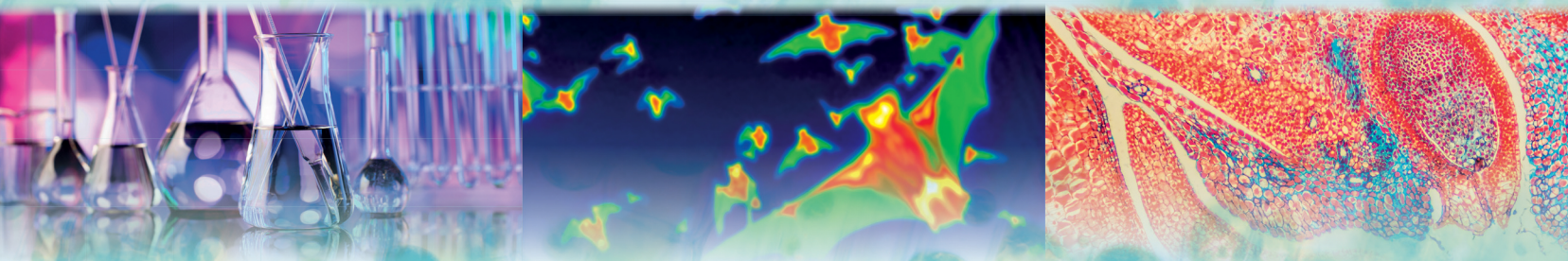
Practical Skills in BIOLOGY

Seventh Edition



Pearson

Practical Skills in Biology

28 Recording data in the laboratory and field

In contrast to the early years of your degree studies, where your practical work and reporting will often by guided by detailed schedules (p. 123), in subsequent advanced activities and projects, you will need to master the important skills of recording and managing data. This is important for the following reasons:

- **an accurate record helps when using information later,** perhaps for exam purposes or when writing a report
- **using appropriate recording procedures enables you to practise important skills** such as scientific writing, drawing diagrams, photography and imaging preparing graphs and tables and interpreting results
- **analysing and writing up your data as you go along prevents** backlogs and helps with time management (Chapter 2)
- **you can show your work to a future employer** to prove you have developed the skills necessary for recording and reporting your work; in industry, this is vital so that others in your team can interpret and use your results.

Learning from your results – effective recording and analysis of your data may suggest options for subsequent experiments. This is especially true for extended practicals and project work.

KEY POINT An effective record of your practical work should:

- outline the purpose of your experiment or observation
- provide details of all materials and methods used
- record all relevant information about your results/observations
- provide an initial visual representation of the data
- note your immediate conclusions and any suggestions for further work.

Recording data in the laboratory

Although the traditional paper-based bound notebook (p. 123) is still favoured by some, laptop computers are now widely used for data recording. Computer-based recording offer several advantages, including ease of transfer of recorded data between applications for further analysis together with ease of back-up and storage.

While individual observations (for example, temperature) can be noted in text form, data collection tables are often the most appropriate way to record large amounts of information. It is often best to tackle this using a computer and spreadsheet; once prepared, you can either record the data directly into the cells of the spreadsheet or use a print-out for 'hard copy' recording. When preparing a table for data collection, you should:

Keeping a record – storage and retention of back-up copies of primary data from research projects and postgraduate work is often covered by a specific code of research conduct – check with your supervisor to see how this is handled at your institution.

Recording primary data – never be tempted to jot down data on scraps of paper: you are likely to lose them and you may forget what individual values mean.

1. **Use a concise title, or a numbered code for cross-referencing.** Including the date in your file name can be useful.
2. **Decide on the number of variables to be measured and their relationship with each other and lay out the table appropriately:**
   (a) The first column of your table should show values of the independent (controlled) variable, with subsequent columns for the individual (measured) values for each replicate ('rep') or sample (Fig. 28.1(a)).

(a)

Level of controlled variable	Measured variable		
	Replicate 1	Replicate 2	Replicate 3
1			
2			
3			
4			

(b)

Treatment	Measured variable	
	Organism 1	Organism 2
A		
B		
C		
D		

(c)

Time	Measured variable	
	Control	Treated
1		
2		
3		
4		
5		
6		

Fig. 28.1 Example layouts of tables for recording data: (a) measurements on replicates at different levels of a controlled variable; (b) responses by two organisms to a range of treatments; (c) time course of responses in control and treated specimens. Note the grid-like nature of these tables used for ease of data entry compared with the 'horizontal lines only' style used for formal presentation of tables (Chapter 76).

(b) If several variables are measured for the same organism or sample, each should be given a row (Fig. 28.1(b)).

(c) In time-course studies, each time point should be a separate row – put the replicates as columns grouped according to treatment, with the rows relating to different times (Fig. 28.1(c)).

3. **Make sure the layout reflects the order in which the data values will be collected.** Your table should be designed to make the recording process as straightforward as possible, to minimise the possibility of mistakes. For final presentation, a different arrangement may be best, particularly where data values have been manipulated or transformed prior to presentation (Chapter 74).
4. **Consider whether additional columns are required for subsequent calculations.** Create a separate column for each mathematical manipulation, so the step-by-step calculations are clearly visible. Spreadsheet software and formulae (Chapter 75) can help avoid mathematical errors for repetitive calculations.
5. **Allow sufficient time within your experimental protocol to record quantitative data accurately.**
6. **Record numerical data to an appropriate number of significant figures,** reflecting the accuracy and precision of your measurement (p. 590). Do not round off data values, as this might affect the subsequent analysis of your data.
7. **Prepare blank copies of data recording tables if your experiments or observations will be repeated.**
8. **Explain any unusual data values or observations in a footnote.** Do not rely on your memory.

Labelling your records – always ensure that your data table/notes includes the date when the recordings were made, plus all relevant details of the observation or experiment.

Recording notes on paper – bear in mind the following advice:

- A bound notebook is your best option, as you are less likely to lose pages.
- If you need to use loose paper, make sure each sheet is dated and easily identifiable – either paste these into your notebook or file consecutively in a ring binder (the same applies to any traces, printouts and graphs produced by instruments).
- Write with a pencil, so that mistakes can be corrected easily.
- Write clearly, taking special care that individual numerals cannot be confused.
- Use a tally chart (p. 556) if recording events – this will also provide an 'instant' histogram of your results.

Recording details of project work

The recommended system is one where you make a dual record.

Primary record

This is the initial record, made at the bench or in the field. In this, you must concentrate on the detail of materials, methods and results. Include information that might prove useful in error tracing: for example, if you note how a solution was made up (exact volumes and weights used rather than concentration alone), this could reveal whether a miscalculation had been the cause of a rogue result. Note the origin, type and supplier of any chemical(s) and organism(s) used. Make rough diagrams to show the arrangement of replicates, equipment, etc.

Using electronic laboratory notebooks – a number of companies now offer software products for data recording in labs (e.g. LABtrak). However, these are mainly used by industrial companies to assist them to comply with regulations assuring quality and data security. For student purposes, standard software such as a word processor, spreadsheet and possibly a database should be satisfactory.

Considering formal aspects of keeping a record – the diary aspect of a record can be used to establish precedence (e.g. for patentable research where it can be important to 'minute' where and when an idea arose and whose it was); for error tracing (e.g. you might be able to find patterns in the work affecting the results); or for explaining your activities to a supervisor.

Analysing your data as soon as possible – always consider your data immediately after collection as this may influence your subsequent activities.

- Generate graphs of your data, since these can be particularly valuable for indicating trends, highlighting differences, etc.
- Carry out statistical analyses (Chapter 80) before moving on to the next experiment because apparent differences among treatments may not turn out to be statistically significant when tested.
- Write down any conclusions you make while analysing your data: sometimes those that come to mind at the time of doing the work are forgotten when the time comes to write up a report or thesis.
- Note ideas for further studies as they occur to you – these may prove valuable later. Even if your experiment appears to be a failure, suggestions as to the likely causes might prove useful.

The basic order of the primary record should mirror that of a research report (see p. 82), including: the title and date; brief introduction; comprehensive materials and methods; the data plus any initial analysis; and short conclusions.

When creating your primary record, take care not to lose any of the information content of the data: for instance, you should record every individual data measurement, rather than just a mean value, as this will enable you to use statistics to describe the variability within the data set (Chapters 79 and 80).

Secondary record

Use your primary record to produce a secondary record that is better organised and presented. This should be in electronic format (for example, a file produced using a word processor). Your secondary record will be used when discussing results with your supervisor, and when writing up your report or thesis – in some instances, this record may be part of your course assessment. Although the text should retain the essential features of the primary record, it should be more concise and the emphasis should move towards *analysis* of the experiment or observation. Outline the aims and objectives at the start and link the data set to others in a series (for example, 'Following the results of Expt D24, I decided to test whether . . .'). You should present data in an easily understood format, for example, as tables of means or as summary graphs. Use appropriate statistical tests (Chapter 80) to support your analysis.

The dual method of recording outlined above deals with any limitations of hand-written notes taken at the bench or in the field. Producing a second, neater version forces you to consider again details that might have been overlooked in your primary record and provides a duplicate in case of loss or damage.

If you find it difficult to decide on the amount of detail required in Materials and Methods, the basic ground rule is to record enough information to allow a competent scientist to repeat your work exactly. You must tread a line between the extremes of including pedantic fine detail and the omission of information essential for a proper interpretation of the data – better perhaps to err on the side of extra detail to begin with. An experienced lab worker can help you decide which subtle shifts in technique are important (for example, batch numbers for an important chemical, or when a new stock solution is made up and used). Many scientific advances have been made because of careful observation and record taking or because coincident data were recorded that did not seem of immediate value.

There are many ways to reduce the labour involved in keeping a record. Do not repeat Materials and Methods for a series of similar experiments; use devices such as 'method as for Expt B4', or give each method a unique name/code. A photocopy might be sufficient if the method is derived from a published source (check with your supervisor). To save time, prepare blank checklists, worksheets and tables for future use.

Recording fieldwork – additional requirements

The main problems you will encounter in the field are the effects of the terrain and weather while taking a primary record and the distance you might be from a suitable place to make a neat secondary record of your results. Voice recording software – for example, using a smartphone or a

digital audio recorder – can help overcome problems of terrain and weather. An 'action camera', such as those made by GoPro®, will give you both video and audio recording. Aim to make your secondary record as soon as possible, so that your memory is fresh, in case these are any issues with poor quality sound or images.

Laptop-based recording may be convenient in some field situations but may not be appropriate if poor weather is a possibility, or if there is no convenient method for charging the computer's battery. For these reasons, paper-based note-taking is often preferred for fieldwork, in which case you should:

- **Select a suitably sized notebook** – a small notebook should fit into your coat pocket.
- **Use a pencil** as ink pens such as ballpoints smudge in wet conditions, are temperamental in the cold and may not work at awkward angles. Do not forget to take a sharpener and eraser.
- **Prepare well** to improve the speed and enhance the quality of your field notes – the date and site details can be written down before setting out and blank tables can be prepared in advance.
- **Transcribe field notes to a duplicate record** at your base each time you return there. There is a very real risk of your losing or damaging a field notebook. Also, poor weather may prevent full note-taking and the necessary extra details should be written up while fresh in your memory.
- **Use photographs to set data in context,** when appropriate – check that you have captured suitable images before leaving the site. Chapter 44 gives further advice on digital cameras/images.

Taking notes in wet weather – notebooks with reusable waterproof pages are available, though relatively expensive. A simpler alternative is to protect your notebook with a clear plastic bag large enough for you to take notes inside.

Another useful approach for field recording is to use a data logger – also known as a data recorder. Measurements from one or more sensors can be recorded at defined intervals over a known period of time, stored temporarily in the instrument's electronic memory ('log'), and then downloaded to a portable computer when convenient. The information is then transferred to a data bank back at base. Advantages of data loggers include the benefit of automatically collecting measurements over time periods that are not feasible for individual field workers, enabling a comprehensive data set for environmental variables such as temperature, light, humidity, etc. However, when using a data logger, you should make back-up copies of each period's data as soon as possible, otherwise data may be lost if the recording instrument's memory is cleared or overwritten after reading, or if the logging machine fails.

Using communal databases to record research information

When carrying out project research as part of a research team, you may need to use their communal databases for recording purposes. These avoid duplication of effort and ensure uniformity in techniques. You will be expected to use the databases carefully and to contribute to them properly. They might include:

- **a shared file of common techniques** (for example, how to prepare growth media or solutions) – you may be asked to add your own methods to this listing

SAFETY NOTE Maintaining and consulting communal lab records – these activities may form a part of the safety requirements and quality standards for working in a laboratory.

- **a set of simplified step-by-step instructions for use of equipment** – manuals are often complex and poorly written and it may help to redraft them, incorporating any differences in procedure that have been adopted by the group
- **an alphabetical list of suppliers of equipment and consumables**, to which you could add
- **a list of chemicals required by the group** and where they are stored-here, you might be expected to record what you use, to help with reordering
- **the risk-assessment sheets for dangerous procedures** (p. 125) – you will need to consult these, and add to them for new techniques you use
- **the record book detailing the use of radioisotopes and their disposal** – here, you must note your usage (Chapter 72).

Sources for further study

Anon. *Suggestions for Keeping Laboratory Notebooks.* Available: https://otl.stanford.edu/suggestions-keeping-laboratory-notebooks Last accessed 11/03/21. [A Stanford University website that looks at the laboratory notebook from the patenting perspective.]

Anon. *Aquascribe.* Available: https://www.aquascribe.co.uk/ Last accessed 11/03/21. [Sales website for Hawkins and Manwaring Ltd, manufacturers of waterproof papers and notebooks suitable for field use.]

Kanare, H.M. (1985) *Writing the Laboratory Notebook.* American Chemical Society, Washington, DC. [Text is available in PDF online at: https://files.eric.ed.gov/fulltext/ED344734.pdf]

Pechenik, J.A.A. (2015) *Short Guide to Writing About Biology*, 9th edn. Longman, Harlow.

STUDY EXERCISES

28.1 Design a primary data collection table for a behavioural study. Imagine you wish to describe the feeding behaviour of birds at their nest. You wish to study the nature of the food, the relative participation of both parents, and the frequency of visits during the daytime with a view to analysis using a spreadsheet.

28.2 Outline the advantages and problems that would be associated with using a digital audio recorder to record data. Consider the behavioural study described in Study exercise 34.1 as an example.

28.3 Design a secondary record table for the collection and analysis of a set of count data for the number of bacterial colonies developed in each of ten replicates for each of five different treatments. Assume that you need to calculate means, variances, etc., and then to compare the results for each treatment.

Answers to these study exercises are available at www.pearsoned.co.uk/practicalskills

29 Drawing diagrams

Drawing has an important place in undergraduate practical work, because of its role in developing skills in visual observation. You need to look at a specimen very carefully to be able to draw it accurately. Also, labelling a diagram forces you to think about the component structures, their positions and roles.

Strictly, a *drawing* is a detailed and accurate artistic representation of a specimen, essentially requiring no biological knowledge. This level of artwork is not required for normal practical work. A *diagram*, on the other hand, is a stylised representation, showing only the most important features in a sketch that is accurate in its general proportions. Biological knowledge is required to select aspects for inclusion and to decide what detail to ignore. Diagrams are often called 'figures' in formal scientific writing, and are sometimes referred to loosely as 'drawings'.

Referring to figures in reports – if producing several diagrams, graphs, etc. for a formal report, number them consecutively as Figure 1, Figure 2, etc., and use this system to refer to them in the text.

KEY POINT You may not feel confident about being able to produce quality diagrams in practical classes, when the time allowed is limited. However, the skills required can be learned by following the guidelines and techniques explained below.

Creating an effective diagram

This requires both planning and careful implementation. The first step is to consider the purpose, type and location of your drawing – Box 29.1 provides further guidance. Once you have made these decisions, you can determine the size and position of your diagram – this should be as large as possible, remembering to leave space for legends and labels.

Most diagrams are drawn in pencil in practical classes, to allow corrections to be made. Propelling pencils are useful for ensuring constant (narrow) line thickness but they do not allow you the flexibility to vary line thickness as you can by changing the angle of an ordinary pencil. If you prefer to use an ordinary pencil, sharpen it frequently. Invest in a good-quality eraser – those of poor quality often smudge badly – and frequently clean its working surface on a spare piece of scrap paper. Always use plain paper for drawing, and if you are asked to supply your own, make sure it is of good quality (of suitable weight/thickness and surface texture). Use pen and ink to create line drawings for illustration purposes in posters, project reports, etc. Follow any guidelines regarding use of colour (usually not required). Computer drawing software can also provide good-quality output suitable for these tasks.

Box 29.1 How to produce an effective diagram

1. **Decide exactly what you are going to draw and why.**
2. **Choose how large your diagram should be.**
3. **Select where you are going to place your diagram on the page.**
4. **Start drawing**. Draw what you see, not what you expect to see. Box 29.2 provides more detailed guidance.
5. **Label your diagram carefully and fully.**
6. **Give your diagram a title, scale and legend**. Where appropriate, include organism, classification, part drawn, orientation, stain(s), magnification or scale bar.