13 The Laboratory Report in the Natural Sciences

The laboratory report is written to describe, document, and communicate the completion of an experiment in a natural science laboratory. When written by a professional scientist, the report presents the results of an original research project, whereas student laboratory reports more commonly present the results of research projects that repeat classic experiments. The report is more often expected of upper-level science students, whereas the laboratory notebook described in chapter 12 is assigned in beginning science courses. Science instructors frequently ask students to write laboratory reports on the following types of questions:

- What are the effects of four different sodium chloride concentrations on the germination of radish seeds?
- How does vigorous exercise affect heart rate and breathing rate in young adult humans?
- What happens when magnesium metal reacts with HCl dissolved in water?
- What is the relation of centripetal force to mass and velocity?
- What amount of work is needed to pull an object varying in mass up an incline varying in height?

Getting started

Before writing the laboratory report you have already accomplished a great deal in the laboratory. You have completed your experiment, and you have kept detailed notes in your laboratory notebook (chapter 12). Now, before you begin writing your laboratory report, you should have an idea of what this report will look like when complete.

The typical lab report is divided into seven sections:

1 Title

2 Abstract

3 Introduction

4 Methods and Materials

5 Results

6 Conclusions

7 References Cited

The laboratory report in the natural sciences has a great deal in common with the report of findings in the social sciences, so you will benefit from reading chapter 11. But note that the natural sciences expect more formalized procedures and format than do the social sciences. The natural sciences are in this way more traditional. And there is indeed a longer tradition of doing and writing up experiments in the natural sciences than in the younger social sciences, where there is more flexibility.

Briefly, the sections of the laboratory report may be characterized in the following way:

Title	Your title need not be a complete sentence, but it should be very explanatory, making clear exactly what was tested in the laboratory exercise.
Abstract	The abstract is a brief summary of your report, not to exceed approximately 250 words.
Introduction	The introduction provides background information and explains the particular problem addressed in the lab exercise.
Methods and Materials	The section on methods and materials is a straightforward explanation of how you did your experiment, including a description of subjects, apparatus, and methods of collecting data.
Results	The results section is a clear, comprehensible description of your data in an organized form. Raw data are rarely presented in a laboratory report, except possibly in an appendix.
Conclusions	This section is a discussion of your results, noting significance and accounting for any discrepancies from predicted results.
References Cited	This section lists all literature cited, including your lab manual or text.

A good lab report should begin, not only before you think about the form of your final paper, but even before you begin the experiment. Before walking into the laboratory, you should know the methods you will use and, if possible, the results you can expect. With this preparation, you will be able to carry out the experiment smoothly, describing the details of your method and recording the appropriate data in your lab

notebook. You should begin to write your lab report as soon as possible after the experiment because even with the aid of a lab notebook, memory fades, and certainly you ought to capitalize as soon as possible on your enthusiasm for telling the scientific community about your results.

Writing the first draft

The section on methods and materials is the most straightforward section in your lab report. Here you explain exactly how you did the research. Your explanation should be detailed and clear enough so that another undergraduate could duplicate the experiment, or so that you could duplicate it five years later. While this latter expectation might seem remote to you now, you may be surprised to learn that your professor almost certainly once or twice found himself, years after the fact, referring to one of his own undergraduate laboratory reports. Whether his experience was bad or good, it has almost certainly influenced him to be a demanding judge of the methods and materials section of your lab report. Nonetheless, this section, like the procedures section in chapter 11, is still probably the easiest part of your lab report to write, and we recommend that in your first draft, you write methods and materials first.

The methods section is always written out in complete sentences using the past tense. Although scientists have long favored the passive voice ("Five chemical tests were performed on each unknown compound"), the active voice is now becoming increasingly popular ("I performed five chemical tests on each unknown compound"), and you should try to use both voices in your writing. Remember that it is acceptable to use "I" or "we" in your lab report, if you are objectively reporting what you did. Statements of feeling are inappropriate, but the word "I" is not the culprit here. In fact, the use of the first person makes your style more direct and, therefore, more scientific. Again, as in writing a laboratory notebook, you should exercise some judgment in deciding which details to report. Do mention details such as the brand and model of complicated apparatus ("Grass polygraph, model 7B"), but omit obvious details, such as the brand or size of common laboratory equipment ("Kimax test tubes, 10 ml").

Unless the lab exercise is relatively brief, you may find that a complete recounting of materials and methods is tedious. Ask your instructor if it is acceptable to cite the directions in your lab manual and then to summarize these directions in your laboratory report. Be very careful to note any differences between the materials or methods in the lab assignment "procedure" and those materials and methods that you actually—either purposely or accidentally—employed in your execution of the experiment.

The methods and materials section is often divided into appropriate subsections. For example, in a biology lab report you might divide this section into "subjects" (the animals used in this experiment) and "appa-

ratus" (the equipment used in the experiment). You will probably want to include figures and tables to clarify approaches and experimental design.

Drafting the results section

In this section you present in a clear, easily comprehensible fashion the data that result from your experiment. Usually, you both write out the results and present them in the form of tables or figures. A figure differs from a table in that a table consists only of words or numbers, whereas a figure includes other graphic forms, such as a drawing, graph, picture, flow diagram, or a computer representation. Well-designed figures are generally easier to comprehend and evaluate than tables because of the visual impact. Be very careful in your design of bar or line graphs, since there are rigid conventions dictating their format. Consult your lab manual and if necessary check your preliminary design with your professor to be certain that you have not misinterpreted any of these conventions. Read chapter 11 for suggestions about graphic presentations of data.

Your written statement of results should highlight the most important or interesting findings shown on your figures or tables. Although you should not draw conclusions about your results in this section, it is perfectly acceptable and even desirable to point out trends or identify special features in the data. You should always give a brief explanation of the experiment that yielded the data you are reporting. Scientists tend to read only sections of research reports, so you should become accustomed to supplying context for each section. Even those reading your whole report will appreciate signposts along the way to let them know where they have been and where they are going. Usually a sentence, or just a part of a sentence, will clarify the source of the data (see figure 13.1).

If you have used statistical procedures to analyze your data, you should present key numbers from your calculations as part of your written section on results. Chapter 11 discussed the inclusion of these analyses in your paper. Again, there are specific conventions governing the presentation of these numbers, and you should either consult your lab manual or ask your professor if you are uncertain. Remember that the word "significant" is not used to describe differences in data unless you have carried out accepted statistical procedures and can specify the level of probability ($p < 0.05$) associated with your use of the word "significant."

Drafting the introduction section

The main body of the lab report begins with an introduction, which provides background information and explains the particular problem addressed in the laboratory exercise. In undergraduate lab reports, the background information is usually found in either the course textbook or the lab manual, and the purpose of the lab exercise is explained in the lab manual or assignment sheet. Therefore, the introduction is usually just a rewriting, in your own words, of the material available in your text.

Your tendency in the first draft of this section may be toward the autobiographical; you may want to say something about what this laboratory exercise means to you. Writer-based prose of this kind will not be

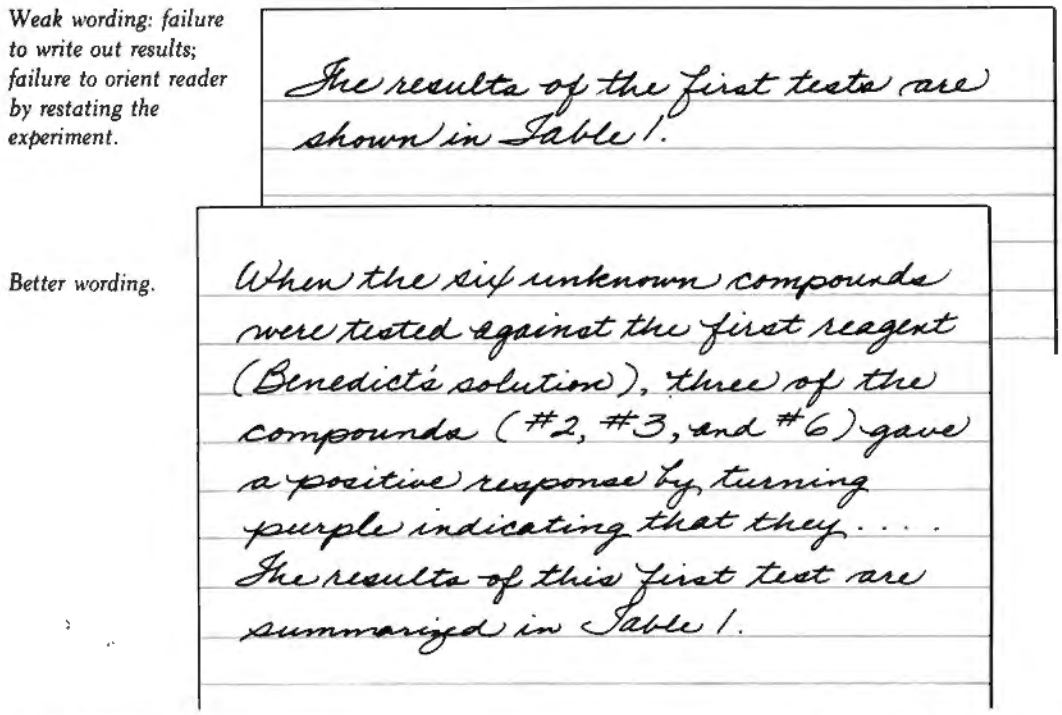

FIGURE 13.1
Providing context in the results section.

appropriate in your finished draft. Even though your own major purpose in doing the lab exercise is to make yourself familiar with a particular laboratory technique, do not say so in your introduction. Keep in mind the broader aim of the laboratory report: to convey information about your work in the laboratory, the why and how, in a form that is clear, explicit, and detailed enough for your readers, who are other apprentice scientists. These apprentice scientists—your classmates—expect you to behave like a scientist, in your writing as well as in your laboratory technique. Your attention to the courtesies of the profession in format and style communicates to your audience that you are learning how scientists behave when they report their research.

As you work to find a clear and explicit form for your introduction, you might try one of these two common sequences:

1 General information; specific information; purpose of the experiment: Begin by presenting the background information and by locating the laboratory exercise within this background information. Close the introduction with an explanation of the purpose of the experiment.

2 History; specific information; purpose of the experiment: Begin by reviewing the historically important research development that led to the

present state of knowledge and by locating the laboratory exercise within these developments. If you choose this strategy, you might also mention additional developments that go beyond the state of knowledge represented by your experiment.

For example, suppose you were introducing a physiology laboratory exercise in which you had measured the number of red blood cells in a given volume of whole blood. If you had enumerated the red blood cells using a special slide (hemocytometer) and a microscope, you might want to mention in your introduction that more sophisticated and entirely automated instruments are now routinely used to do red cell counts in hospitals. Again, close your introduction with a final paragraph explaining the purpose of the experiment. By delaying an explanation of the purpose until the final paragraph, you will have a nice transition to the next section, which will describe the materials and methods that you used in your particular experiment. Although the use of subheadings such as "Materials and Methods" partially relieves the need for transitional sentences, the very best lab reports still prepare the reader for each new section. The resulting clarity is a hallmark of a well-written report.

Your introduction should also reflect a familiarity with both the format and style of writing used in professional research reports and with the more immediate needs of your audience of fellow undergraduates for thorough explanation and clear writing.

The most common writing difficulties in laboratory reports are failures to cope successfully with these demands. Figure 13.2 presents an example of writer-based prose that should eventually be edited.

Drafting the conclusion section

In this section, you present the conclusions you have drawn from your results. You also discuss the importance of your conclusions and try to account for any discrepancies that might have arisen between your results and the predicted results.

In laboratory reports of original research this section is fairly extensive because the new research must be put into the context of previously reported research. In student lab reports, the discussion may be briefer when the results repeat a classic experiment. If your experiment was entirely successful, you can merely report that your results, like the lab results of other science students, again confirm a classic and well-established principle. Be careful to summarize and to cite the statements in your lab manual or textbook that predicted the results. If your professor expects a more extensive discussion section, then you might expand your section by mentioning additional, more detailed information obtained from outside reading. Information of this sort is identical to information used in your introduction, and it is often possible to shift information between the introduction and discussion until a nice balance is achieved.

If your results did not come out as predicted, then you have more to discuss. First you must again justify the validity of your predictions by

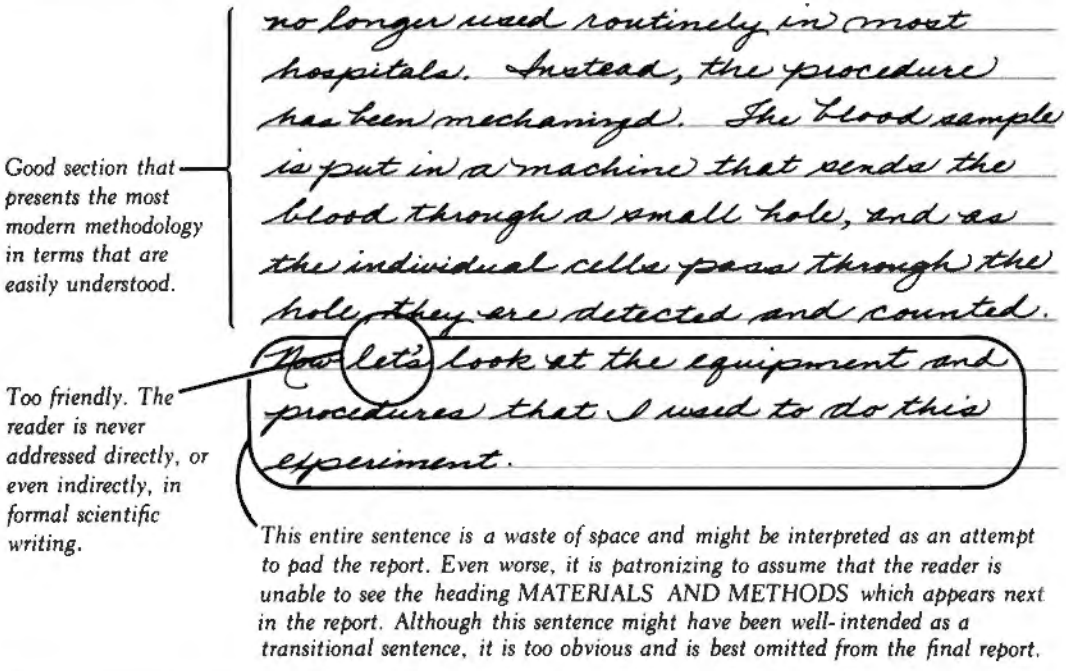

FIGURE 13.2
Writing the introduction to a laboratory report.

locating, summarizing, and citing appropriate material in either your lab manual or in your text. Then you must explain what has caused your particular results rather than the expected results. Unless your own responses are specifically requested by your professor, you should avoid commenting on the pedagogic or entertainment value of the experiment. A comment like, "This experiment was really fun and I learned a lot" is not appropriate.

Drafting the abstract

When the body of your report is complete, you are ready to write your brief abstract. Summarizing your report is a very useful thinking exercise. Abstracts are usually limited to 250 words, and they consist of a single tightly organized paragraph. Your abstract should answer these questions:

1 What methods were used? You should mention important details about the experimental subjects, the approaches, and the procedure. Write these sentences in the past tense.

2 What variables were measured? Use the past tense.

3 What results were obtained? Use the past tense.

4 What conclusions can be drawn from these results? Use the present tense.

A sample abstract from a student laboratory report is illustrated and annotated in figure 13.3. Also see chapter 5 for more general help with summarizing.

Writing a title The final step in writing your first draft is to provide the report with a title. Avoid simplistic titles. ("Biology Lab Report" or "Radish Seed Experiment") and beware of humorous titles ("How Much Salt Can a Radish Take?"). Because of long-standing traditions in scientific reporting, attempts at humor sound strained and inappropriate.

Revising

After you have written the first draft of the various sections, you can get an impression of the final lab report. If it seems too skimpy, search out additional information from more advanced textbooks or even from the original research articles cited in your lab manual or text. You are not usually expected to locate up-to-date research articles, however.

Now your report can be treated like any other first draft, either by sharing it with fellow students or by putting it away for several days. When you return to it with a fresh perspective, consider these questions: Does your title explain the experiment? Does your abstract provide a concise summary of the experiment? Does your introduction thoroughly explain the experiment so that another undergraduate would understand what was done and why? Is your "Materials and Methods" section complete enough so that another person could duplicate your experiment? Are your results clearly written out so that your reader knows what results are particularly interesting? Are your graphs or tables thoroughly labeled, properly titled, and presented in the most comprehensible format? Does your discussion section explain why certain results could be expected? Does it go on to compare your results to these expected results?

Check your draft for correct details of syntax, punctuation, and spelling. Make sure you have used appropriate organizational structure and paragraphing. Use the subheadings for sections described in this chapter. Remember that scientists are often especially sensitive to sloppy presentation.

Now you are ready to add the references section. Although this paper will have fewer references than the scientific review paper (chapter 14), the references are arranged in the same way. As a bare minimum you need to cite your lab manual or the instructor's handout and your textbook. Of course, if you have read additional references, you should summarize them and cite them in your lab report.

Now prepare final copies of your figures or type out tables. To produce professional-looking figures, draw them first lightly in pencil. Then, when you are certain that they are accurate and correctly drawn, go over them with black ink and erase the pencil lines. Avoid using color whenever

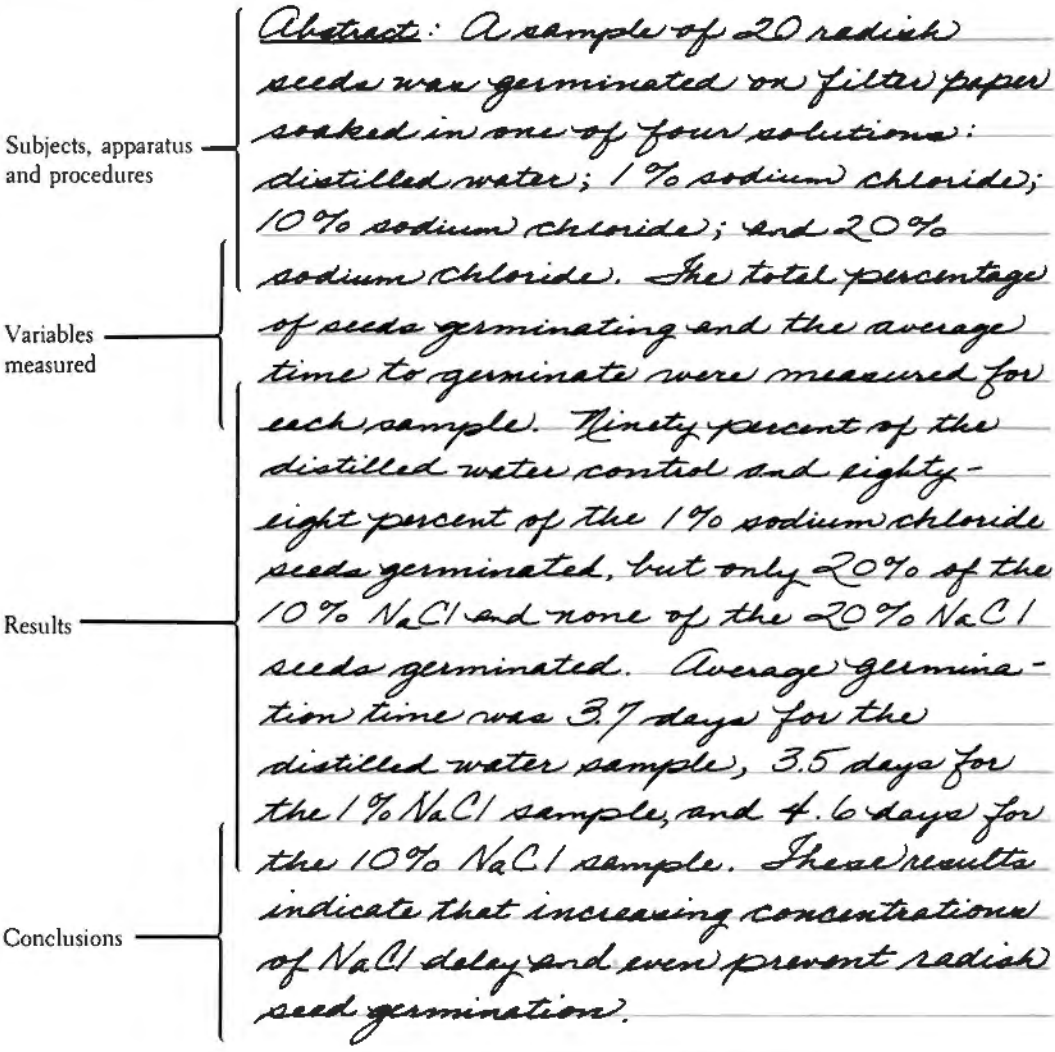

FIGURE 13.3
An abstract from a student laboratory report describing the germination of radish seeds exposed to a distilled water control and three concentrations of sodium chloride (NaCl).

possible. Remember that good scientific drawing, like good scientific writing, puts a premium on simplicity and clarity. Doing a first draft and then revising your drawings can be as useful as doing a first draft followed by revision of your lab report.

Finally, as you prepare the final copy of your report, you should follow the rather rigid conventions of the profession. The title is usually centered on a title page, which also includes your name, the course number, laboratory section, and the date the paper is due. When you use either figures or tables, remember that the figures are consecutively numbered, with an explanatory figure legend below them, and that tables are

also independently consecutively numbered, with a centered title above them. Also remember to mention in the body of your report the presence of all figures that you have put on separate sheets of paper, each with its title above (for tables) or legend below (for figures). Then insert each page into your lab report as the page immediately following the mention of the table or figure in your writing. While this procedure requires that you delay numbering your pages until you have almost completed your report, it is much easier than trying to leave appropriate space on the typed pages of your report.

All this effort will produce a permanent record of your work in the laboratory. Through this activity you will practice skills essential to the scientist. Science proceeds not merely because people do research but because they meticulously publish their procedures and findings to the scientific community at large. Clear and effective writing is more than useful to you as a scientist; it is your obligation.

QUESTIONS

1 What are the seven sections of a laboratory report?

2 What materials belong in the introductory section? Why?

3 What is the purpose of an abstract in a research report?

4 Why is it important to consider your classmates as the audience for a laboratory report?

EXERCISES

1 Compare and contrast the style for reporting findings in the social sciences (chapter 11) and reporting findings in the natural sciences.

2 Using the data from figure 12.1, write a title and introduction for a laboratory report.

3 Using the data from figure 13.2, write a results section and a conclusion section for a laboratory report.