12 Recording Observations in the Natural Sciences

The types of writing that you do in a science laboratory have more in common with writing tasks in the humanities and social sciences than you might think. The topics are different, of course, but for many science assignments you can use modes of writing that you have learned and employed in other courses. For example, as you make notes in your laboratory notebook, you are mainly narrating procedures and describing results. Later, when you write up your lab report, you will classify and analyze your findings in order to draw inferences from them. In the laboratory, however, these writing tasks are used to facilitate a particular method of problem solving, the scientific method.

To understand the role of writing in the laboratory, you must first understand the processes and purposes of the scientific method of investigation. This method is a way to examine and understand the physical world by asking questions and answering them through empirical investigation. In the sciences we derive knowledge from observation and experimentation, and the purpose of the knowledge is to establish (to confirm or disprove) principles by which we understand the physical universe. This method usually begins with an idea or a question, for example, the speculation, which we develop in later chapters, that perhaps the reason that men who are heavy marihuana users develop enlarged breasts is that marihuana acts like a female hormone. This idea must be molded into a hypothesis, or a working thesis ("Let's see if the active ingredient of marihuana attaches to the same chemical binding in the uterus as the female hormone estrogen"). Scientists then test the hypothesis in the laboratory under carefully controlled conditions. They construct an experiment which is designed either to prove or disprove the hypothesis; if successful, this experiment is reported to other scientists (chapter 14).

Writing is central to this discovery and testing process. Without writing, a scientist could not get to the end of an experiment and remember it accurately enough to describe it in the detail necessary for other scientists to replicate it. A report of findings must include an accurate description of the experimental design and a careful narration of the working out of the design in addition to an account of the findings. These essential parts of the report must be constructed from notes.

College freshmen are almost never required to carry out the entire process from formulating a hypothesis to reporting the results of an experiment, but college entry-level courses in science usually include a laboratory experience to introduce students to the methods that scientists use to solve problems. In the first instance, laboratory exercises are designed to acquaint students with course content. By requiring students to report classic experiments or observations, these courses also teach the skills an experienced scientist needs, especially careful technique and thorough recording. These emphases are continued through upper-level courses.

The evaluation of laboratory technique reflects the priorities that instructors attach to the experience. At a minimum, the instructor compares the student's results with expected results (Does the compound synthesized in chemistry lab melt in the correct temperature range, indicating that the synthesis was successful? If not, has the student adequately explained the discrepancy?). In most introductory courses, however, instructors evaluate students' notebooks not only for results, but also for thoroughness and accuracy in describing the experiment. Also, it is common for students to have to study the material recorded in their notebooks so that they can take special quizzes called "lab practicals." These tests are designed to discover whether students are familiar with the procedures as well as the results of laboratory exercises. In brief, science stresses method as well as results, and students need to give attention to understanding and remembering laboratory technique as they carry it out.

It is the purpose of this chapter, and of chapter 13, to familiarize you in detail with the writing demands of laboratory work in the sciences and to prepare you to use writing to become a more effective science student.

Purpose of the laboratory notebook

All experimenters, from entry-level undergraduates to professional scientists, keep a record of laboratory work. This record, regardless of its format, is called a laboratory notebook. Its purpose is to provide a complete and accurate account of the testing of a hypothesis in the controlled environment of the laboratory.

For professional scientists, the laboratory notebook acts as an aid to memory and will eventually provide the details for their research reports (chapter 13). Not only do scientists need a complete and well-organized record of each different experiment, but as they change one variable in the same experiment, they must have detailed records to compare results. Furthermore, research can take months or years to complete, so scientists often have to go back to their early notes to finish a project. Since notebooks are often shared with co-workers, scientists need to give attention to recording in a fashion that can be quickly and easily understood by others. A carefully prepared laboratory notebook may make all the difference in certain legal situations, when the notebook may have to serve as proof of a discovery. In short, working scientists invest great care in their laboratory notes.

While undergraduate notebooks do not serve as many purposes, they are, nevertheless, critically important in their own contexts. They assist you in carrying out, understanding, and explaining your laboratory experiences. They are an invaluable record for review, since you may be studying the material weeks or months after the experience. Your instructor will read your lab notebook to see if you understand the techniques of working scientists. Consequently, it is in your interest to invest time and care in the laboratory notebook.

Writing in the laboratory notebook

Your laboratory notebook might be a commercially produced fill-in-the-blank workbook or a regular notebook in which you record information according to your instructor's directions. Whatever the style, notebooks share a common requirement: all are designed for your original, on-the-spot records of your laboratory activities. As you carry out the assigned procedures, you should record the results immediately. In a workbook, space will be provided; in your own notebook, you should record your notes in complete sentences. Resist shorthand record keeping. Writing complete sentences will ensure that you understand the concepts with which you are dealing. Later on, when you study your lab notebook, full sentences will provide a clear, unambiguous record of your procedures and results. The importance of complete sentences is illustrated in figure 12.1, which shows a sample page from a chemistry workbook.

FIGURE 12.1 (on facing page) *A sample page from a chemistry workbook.* [*From* Laboratory Manual for Chemistry: Basic Concepts and Contemporary Applications *by Leonard S. Wasserman.* © *1974 by Wadsworth Publishing Company, Inc., Belmont, California 94002. Reprinted by permission of the publisher.*]

Notice that the two-word answer "universal solvent" has been marked incomplete. While these words may seem very clear when written, especially in a workbook format, which has a discussion paragraph right next to the question, the meaning will fade, and at exam time you may well have to waste time in deciphering notes that you lazily recorded in abbreviated form. Make your notes complete in themselves.

Writing in complete sentences has another, more immediate advantage. Doing so allows you to know, before you leave the lab, if you understand completely the purposes of the assignment. A complete sentence has a structure that connects ideas and imparts meaning, and scientists, like English majors, need to make and understand connections. Forming your responses in connected discourse reveals gaps in your understanding while the instructor is still available, and allows you to ask intelligent questions about unclear procedures or other difficulties. For example, this question appears in a chemistry lab exercise on solubility: "Why is CCl_4 used to remove nonpolar oils and grease?"

A student who had read the appropriate material in his textbook could be fairly certain, from the wording of the question, that the answer should

Name ______________________ Section Number _____

Unit 6

A Study of Solubility, Water Pollution, and Water Purification

Discussion

This series of experiments is concerned with water pollution and purification. Pure water is a colorless, odorless, tasteless liquid. Because it is a universal solvent, natural waters contain a variety of dissolved compounds, including oxygen, carbon dioxide, and, in many areas, even undesirable substances (pollutants). The properties of solutions must be considered to understand both the pollution and purification of water.

Solutions are mixtures of dissolved substance (the *solute*) and the dissolving substance (the *solvent*). Solutions are generally characterized by:

1. homogeneity
2. absence of settling
3. the non-separation of the solute from the solvent by filtration

When a substance is dissolved in water, depending upon the nature of the solute:

1. the individual molecules may be separated and become hydrated (alcohol in water);

$$C_2H_5OH \xrightarrow{H_2O} C_2H_5OH_{(aq)}$$

2. the ions may be separated and become hydrated (NaCl in water);

$$NaCl \xrightarrow{H_2O} Na^+_{(aq)} + Cl^-_{(aq)}$$

3. each individual molecule may be separated into ions and the ions become hydrated

$$HCl \xrightarrow{H_2O} H_3O^+ + Cl^-$$

Polar water molecules pull apart the ions of ionic compounds and separate them from the crystals. The ions are kept separated by additional water molecules which prevent the positive and negative ions from recombining. In a similar manner, the molecules of polar covalent compounds are also separated and kept apart by the polar water molecules.

Prelaboratory Discussion Quiz

Incomplete answer.

1. Why is water readily polluted?

Universal solvent

Complete answer.

Water is a universal solvent and consequently many compounds, including pollutants, dissolve in water.

2. What are the characteristics of a solution?

3. What occurs when a substance is dissolved in water?

be, "Carbon tetrachloride is used to remove nonpolar oils and greases because it is also a nonpolar compound and, therefore, can dissolve the solid greases. CCl_4 is also miscible with liquid oils." But, at the same time, part of the lab experiment that yielded this answer would also show that soap mixed with water could also dissolve oils and greases. Does this discovery require a more complete, complex answer in which soap and water are compared with carbon tetrachloride? This question should be asked of an instructor before class ends, but to ask it, a student needs to have thought about his responses completely enough to know that a problem exists. Writing provides that occasion.

To make your written answers most useful for immediate understanding or later reference, you should give particular attention to two characteristics of good writing. The first is to write with as much detail as possible. As we said in chapters 2 and 10, observation (and experimentation) should result in concrete and explicit record keeping. Do not estimate; do not leave blank spaces to be filled in later; do not cut corners. The scientific method demands exactness, because scientific theories are based, finally, on hard data.

Second, when narrating procedures, use connecting words to show relationships wherever necessary. Just as philosophers have to show sequence in logical arguments (chapter 2), so scientists must give careful attention to cause-effect relationships and the cumulative nature of scientific experimentation. If appropriate to the format of your lab notebook, you should use words such as *then, consequently, next, because,* and *therefore.*

Revising and correcting the laboratory notebook

Since your notebook is supposed to provide a record of what actually went on in the laboratory, you should make every effort to record the results correctly the first time. Your results should never be copied over to make them neater or better organized. Copying not only wastes time, it introduces the possibility of copying error. Even worse, if your instructor sees a copied version, he may have cause to wonder if you wrote a new version to change results after you realized that the original results failed to confirm the hypothesis.

If you do make errors while recording in the laboratory, correct them as clearly as possible either by erasing or by crossing out and rewriting on the original sheet. If you are uncertain about your on-the-spot composing skills, work out your answer on a piece of scrap paper, then, before you leave the laboratory, copy the answer onto your lab sheet.

If you do make an uncorrectable mistake in your lab notebook, do not tear the sheet out. Simply fold the sheet lengthwise and mark "omit" on the face side. Similarly, if you need to add sheets to your notebook (physiograph tracings or data-laden note sheets), attach them permanently to the appropriate pages. Do not use paperclips.

Format for the laboratory notebook

For many laboratory notebooks, especially in entry-level courses, the formats are already developed by the publisher of your workbook or by your instructor. You will receive instructions for that sort of lab sheet in class or in the lab.

If no format is provided, or if your instructor asks you to develop your own, your obligation is to work out a format that allows you to communicate all major features of an experiment. Every report of an experiment is divided into at least five sections: *title*, *purpose*, *materials and methods*, *results*, and *conclusions*. If your task is a multiple-experiment exercise, you will have to decide whether you should treat each experiment separately or subdivide the major sections within a single report.

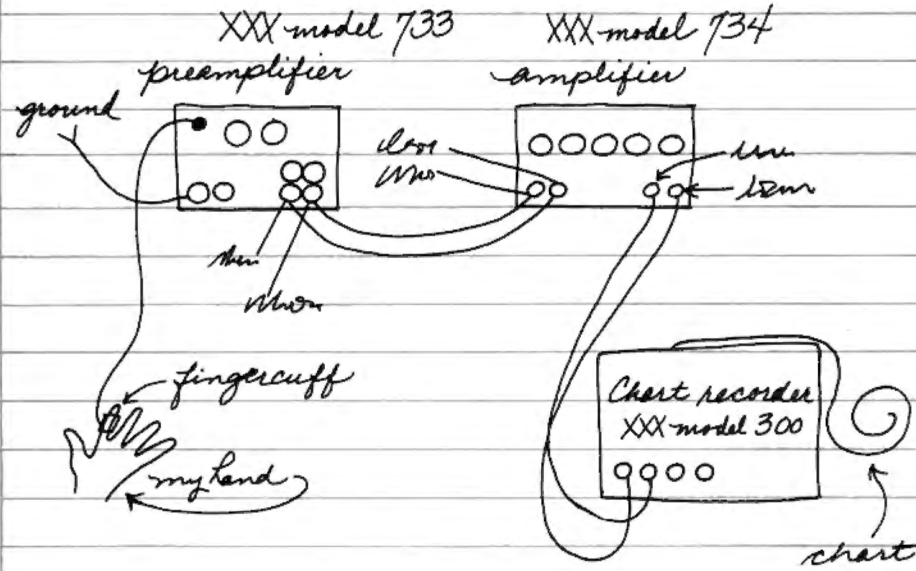
Develop a title that describes your experiment. Thus, "The Relationship between Human Pulse, Blood Pressure, Respiration, and Exercise" is a better title than "Experiment #9, Circulation." Next, state briefly, in complete sentences, the purpose of the exercise. Often you can copy the title and purpose directly from your lab manual, giving due credit, of course, to the author of the manual. You will learn more, however, if you record the purpose in your own sentences.

The materials and methods section contains a summary of the procedures used in the experiment. Write out these procedures in complete sentences and organize them into logical paragraphs. Then describe your equipment. You should identify the major pieces of apparatus, unusual chemicals, and laboratory animals. Your identification should also be detailed enough to allow a reader to distinguish between sizes or types of the same equipment (instead of "physiograph," write "physiograph, Grass model 7B"). Drawings illustrating complicated equipment setups and notes on the particular settings used to obtain results from equipment are sometimes useful additions to your lab notes. Professional scientists characteristically record this kind of detail. Figure 12.2 illustrates a page from a physiology notebook showing a record of how equipment was set up and the dial setting that was used to obtain the data.

Sometimes you may paste in a photocopy of the methods section from your lab manual, and you should certainly incorporate any special lab handouts into your notebook. In both cases, read through the material and record any changes you made in the methods. For example, if the chart paper from your physiograph recorder can be set to run at either 1 cm per second or 5 cm per second, but not at any speed in between, you would obviously have to change a statement in your photocopied lab manual methods that says, "with the paper speed at 2 to 3 cm/sec."

The results section is the core of your laboratory record, and it usually consists of a combination of tables or figures and written explanations. Whenever possible, you should make preparations before you enter the lab for tables on which you expect to record data. You can then easily fill in the raw data.

pulse - pressure expt (cont.) 3/31/81



Dial settings:

Preamplifier

[illegible]: 7.3 ← With our first subject (Joe Smith) this setting worked fine. But we had to increase setting to 8.5 with our second subject (Judy Jones)

[illegible]: 6.0

[illegible]: — N.A.

[illegible]: — N.A

Amplifier

[illegible]:

[illegible]:

Other dials don't matter (N.A)

Chart recorder speed was set at 3 cm/sec.

FIGURE 12.2
(on facing page)
A page from a student physiology notebook, showing details needed in the materials and methods section.

You cannot always anticipate events in the laboratory, so no matter how carefully you prepare in advance, there may be times when you find yourself jotting down notes on any convenient piece of scrap paper, even on a paper towel. In that case you should permanently attach these notes to the results section, along with the table you develop to present data. If you use data from chart recorders, then it is appropriate to attach the printout to the results section (figure 12.3).

The conclusion section includes a general summary of the outcome of the experiment (Did the results confirm previous results? Were the results what you had expected?) and possible reasons for the results if they were not what you expected. If your results did turn out as expected, you should comment on that fact. For example, in a discussion of a physiology experiment on pulse pressure, the student included a photocopy of the lab manual's figure illustrating a typical pulse-pressure record and commented on the similarity between the illustration in the manual and the actual recording he had made in the lab. The questions posed in your lab manual should also be answered in this section.

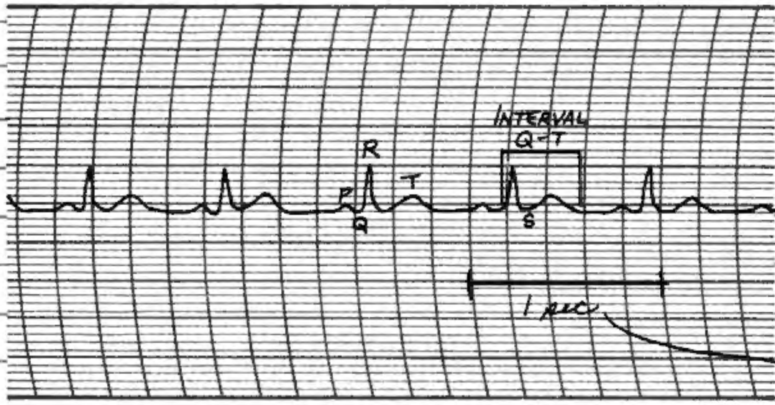
The research notebook

The research notebook is the most advanced form of lab notebook. It contains the complete record for a program of original research, from the development of a hypothesis to the rationale, methodology, results, and conclusion for each experiment. These notebooks are introduced and used primarily in upper-level courses. Although the general procedures used in the research may be described in technical manuals or published research reports, the advanced science student often makes specific changes in methodology necessary for that individual research project. Also, the advanced science student is always on the lookout for unexpected results. Therefore, it is especially important that a research notebook be complete and up to date. In addition, undergraduate research notebooks should be reasonably neat and well organized, for they are usually shared with a faculty adviser.

The format for the research notebook is variable, not only because of individual record-keeping styles, but also because of the physical characteristics of the data. For example, three-ring binders or even manila envelopes are more appropriate than composition-style notebooks if the data appear as long, unwieldy tables and figures. Students, however, usually select a combination of a chronological notebook (a day-by-day account of research activities) and the lab notebook format described in the preceding pages.

We have discussed at several points in this chapter the purposes and uses of laboratory notebooks. In entry-level courses, most of the uses are instructional. However, laboratory notebooks are also indispensable sources for other types of scientific writing. Like research notecards in history or philosophy, lab notebooks can provide the foundation for a full-electrocardiogram expt (cont) 4/17/81

The QRS complex of the electrocardiogram



This recording done at faster paper speed (25 mm/sec) than previous recordings so that the electrocardiogram would be more spread out for easier labelling.

This recording done at lead V_6 (subject = Joe Smith)

left arm
rt. arm — terminal
left leg

chest electrode, + terminal

Selector switch in the $V_1 - V_6$ position

put on midaxillary line, even with left nipple fledged paper. The next chapter will describe such a project, the laboratory report.

QUESTIONS

1 What is the scientific method of investigation?

2 Why is the strict adherence to the scientific method so important in laboratory experiments?

3 What are the primary purposes for keeping a laboratory notebook?

4 What are the most important rules for keeping a laboratory notebook? Identify the purpose for each rule.

EXERCISES

1 Write out in prose form a laboratory experiment that you have recorded in a preprinted laboratory manual. What advantages and disadvantages do you find with each method?

2 As a class, discuss the major similarities and differences between observing in the social sciences and in the natural sciences.

3 Write prose answers to questions two and three on the sample page from the chemistry workbook in figure 12.1.

FIGURE 12.3
(on facing page)
A page from a student physiology notebook, showing information recorded in the results section.