Appendix II
How to Write a Scientific Paper

A good scientist also must be a good writer. All the brilliant research of a lifetime is of little use if the investigator cannot effectively communicate new findings to his or her colleagues.

Go to the university's library and peruse some of the many scientific journals available there. Journals such as *Science, Copeia, Biotropica* and *Ecology* offer good examples of formats commonly used for scientific papers, though required format varies from journal to journal. When you publish your own work, it is necessary to check the specific requirements of the journal to which you are submitting, to be sure that your paper is not rejected simply because it is in the incorrect format.

Most scientific publications consist of a descriptive **title**, **abstract, introduction, methods, results, discussion** and **literature cited.** You will be using this format when you write a report on two of the experiments conducted this semester. This outline instructs you how to write each of the six components of a scientific paper. Label each component as shown below.

title

The title of your paper will be read by the most readers, and it is the title that often will determine whether the rest of your paper will be read. It should describe *specifically* the contents of your paper. Generally, the name of the organism being studied is also included. Under the title, list your name, the date and your institutional affiliation (In case you don't know. . . it's the University of Miami.)

abstract

The purpose of the abstract is to allow a reader to determine, with a very quick scan, the topic of your paper, your experimental methods, and your conclusions. Although the abstract appears *first*, it is written *last*. In one double-spaced paragraph, offset from the rest of the paper, give a skeletal outline of your purpose (one sentence), methods, (one to two sentences), results (one to four sentences) and conclusions (one to two sentences). Do not cite literature references in the abstract.

The abstract is NOT merely an introductory statement. If you were actually to publish your paper, its abstract would appear in *Biological Abstracts,* a massive series of books containing nothing but the abstracts of scientific papers written in a given year. (The series is available for your perusal in the reference area of the library.) An investigator searching for information on a particular subject can look up and read abstracts--rather than an entire paper--to determine whether a particular paper is relevant to his/her own work. If it is, s/he can then obtain the actual journal and the complete publication for a more detailed account.

introduction

This section can be written even before you begin your experiment. In one to several paragraphs, give *specific* background information on your project. Include a statement of purpose, the ideas that led to your experiment and what you are trying to demonstrate. **When making a statement that is not common knowledge, you must**

cite the source of your information (see "literature cited" for instructions on the proper citation format). Unless absolutely necessary, however, DO NOT USE DIRECT QUOTES! Instead, read, learn and *paraphrase* the knowlege.

The introduction is the proper place for you to state your **question**, your **hypotheses** (null and alternative) and your **predictions**. Include a summary of expected results (in terms of the null hypothesis) and *why* you expect those results. Remember: if you have not mentioned expected results in your introduction, you cannot suddenly claim that your results "confirm the prediction" later in the paper. Amazing as it may seem, we see this error quite often!

methods

The purpose of your methods section is to enable a reader to duplicate your experiment and test whether your results are reproducible. **Using past tense** (you are not writing a cookbook), you must describe all materials and procedures you used. **List concentrations, amounts, etc., of reagents in neat tables and *refer to these tables in the text!*** (Example: "Concentrations and amounts of enzyme and substrate used in Experiment #1 are listed in Table 1.") Do not describe the same procedure over and over for nearly identical experimental trials. Describe your general experimental procedure only once, then note which procedures were changed for subsequent trials.

Caution! Don't get carried away with detail! It is not important that you used a #2 pencil to record your data in a spiral notebook on a slate table in a spacious laboratory. Also, most readers are aware of the methods one can use to boil water. However, it is important to tell the reader that you used a 0.24 Molar solution of a particular reagent, what type of apparatus you used, and what statistical tests you used to analyze your data. Use your judgement and common sense! **Assume that your reader has some inkling of scientific procedures and knows good lab technique. Don't teach him/her about it in your lab report.**

DO NOT INCLUDE ANY DATA OR CONCLUSIONS IN THIS SECTION!!

results

Your results must be described in one to several **prose** paragraphs. *Never* give long lists of numbers in your prose text. List such results in neat tables or in clear figures. You must refer to each of your figures and tables somewhere in the text of your paper. For example: "Increased reaction temperatures resulted in a higher rate of reaction (Figure 5)."

A **table** consists of neat columns of numbers or words. You should refer to it as "*Table 1"* (or 2, or 16, etc.) in your text and in its legend, which appears *above* the table. A photograph, drawing, graph or other illustration is called a **figure**. It should be referred to as "*Figure 1"* (or 3 or 10, etc.) in your text and in its legend, which appears *below* the figure. Be sure you know how to create figures and tables correctly before you include them in your paper.

Do not alter your sacred data! Report exactly what happened in your experiment, even if it is not what you expected. You will have ample opportunity to explain deviations from the expected in the next section.

DO NOT INCLUDE ANY DISCUSSION OR CONCLUSIONS IN THIS SECTION!!

discussion

This is the main body of your paper and not merely a re-statement of your results. In your discussion, you must analyze and explain your results. Follow these simple guidelines to write a good discussion.

1. Link your results to your original hypotheses.
2. Do you accept or reject your null hypotheses? Why or why not?
3. Explain your experimental observations in *specific* terms. Describe what has happened in terms of molecular interaction, physics (kinetics), behavior, etc. DO NOT make statements such as: "The reaction was faster because it had a greater reaction rate." We hope we do not have to explain the absurdity of this.
4. The earth's magnetic poles will not reverse themselves if your results are not what you expected. If they are not, then simply try to explain why your data show such unexpected results. Be logical, imaginative. and--above all--HONEST.
5. Discuss possible sources of error and how they might have affected your results.
6. Compare your results to those of similar experiments published elsewhere.
7. Draw overall conclusions--give summary statements.

This is your chance to show us your amazing capacity for creative, scientific thought. Feel free to refer to published literature on the subject, but don't be shy about offering your own insights into your experimental results.

Be forewarned. This section is usually worth more than half of the entire paper's grade. If you do not give detailed, intelligent explanations for your observations, you have *not* written a scientific paper and you will not receive *credit* for one. If your lab instructor has imposed a page limit, don't limit the discussion--cut down somewhere else!

literature cited

"Literature cited" is exactly that. **When you state a fact that is not common knowledge, you must cite the source of that information.** What source, you ask? Your lab manual. Your text book. Your lab instructor. Scientific literature (Yes! UM has Biological Abstracts and a library chock full of scientific journals!).

Citation format differs somewhat from journal to journal, and here we provide you with the format we require for The Journal of University of Miami First Year Laboratories. When you cite a reference in the *text* of your paper, write the author's last name (if there is more than one author, add "et al." after the first author's name) and the year of the source material's publication in parentheses immediately after the pertinent information. For example:

Reaction rate may vary depending upon the pH of the solutions because enzymes may be denatured in very acidic or very basic solutions (Campbell *et al*., 2003).

(Note: "et al." is a Latin abbreviation meaning "and others." It is used only in the text reference when there are more than two authors. However, when writing the reference in you Literature Cited section, you must list every author's name individually, and not use "et al.")

In some cases, you may wish to include information you received verbally from an instructor or other authority. This type of citation is known as a personal communication, and should be cited in the text of your paper as follows: "Lemmings never actually jump off of cliffs into the ocean during migration. The ones shown in that Disney film were actually herded off the cliff with flame throwers (D. Krempels, pers. comm.)."

Personal communication citations should be avoided for any information that is available in published form. These types of citations are usually reserved for information that is not common knowledge, but not published in a scientific text. Personal communication citations should NOT be listed under literature cited. They should appear only in the text of your paper.

At the very end of your paper, after the Discussion section, references should be listed, in alphabetical order, in a section entitled Literature Cited. **Include all citations mentioned in the text of your report, but DO NOT list a reference if you have not cited it in your report!** Use the format shown in the following examples.

FOR A BOOK:

Henderson, S. T. 1970. Daylight and its spectrum. American Elsevier: New York.

FOR A JOURNAL ARTICLE:

Schwalm, Patricia A., Priscilla H. Starrett and Roy W. McDiarmid. 1977. Infrared reflectance in neo-tropical leaf-sitting frogs. Science 196: 1225-1227.

A word about web sites...

It seems to have become fashionable for students to cite web sites in their scientific papers. Please be forewarned that this is NOT a generally accepted practice. Many web sites that tempt students with "scientific" information have not been subject to rigorous peer-review. They may contain good information, but they also could be rife with personal opinions, half-truths, errors and inconsistencies. There is little way for the casual reader to be sure. A web site may be up one day, and gone the next. How reliable do you think such information might be?

If you absolutely cannot find information about your subject anywhere except a web site, then please ask your instructor whether s/he is willing to allow you to cite a web site URL as a reference. In any case, you would be wise to avoid any web sites with ".com" or ".org" designations. Other domains, such as ".edu" and ".gov" may be more reliable--but take everything you read on the www with a grain of sodium chloride, unless it is a reprint of a peer-reviewed journal article.

don't make common mistakes!

1. **DO** use correct grammar and spelling. Yes, this is a science class, not an English class. Therefore, we assume you already KNOW how to use the President's English (except that we hope you know the correct pronunciation of the word "nuclear") and we need not take on the arduous task of correcting and slashing points from a poorly written report**. But we shall if we must.**
2. **DO NOT** write in the second person. Use either first or third person. RIGHT: "I then grabbed a flask and heated it until it blowed up real good." WRONG: "You then grab a flask and you heat it until it blows up real good."
3. **DO NOT** write in future tense. Write in present or past tense (Journals vary in their requirements for tense). Use the same tense throughout your paper.
4. **DO NOT** pad your prose with flabby pseudoexplanatory phrases such as "It is important to do this because..." or "It is a fact that..." This is just bad style.
5. **DO NOT** use subjective adjectives ("*good* result" "*bad* result" "*clearly* demonstrates" "*extremely* obvious" etc.). Let the reader judge the data.
6. **DO NOT** state that your purpose is "to learn all about the phenomenon of...." **It is <u>NOT</u>.** Your purpose **IS** "to test the effect of ..... on ....." You are writing a scientific paper, not "What I did in school today."
7. **DO** write as though you had designed the experiment. Do not say, "We were required to..." or "The procedure required that we..." That sounds so *painful*. Okay, so it was. Humor us anyway.
8. **DO** use your own words. Paraphrase cited sources. **Unless absolutely essential to convey some subtle point (and it almost never is) by quoting an author's exact words, DO NOT USE DIRECT QUOTES, even if placed in quotation marks (" ").**
9. **DO NOT** use chatty prose. RIGHT: "The results appear to refute the null hypothesis." WRONG: "The results kind of surprised me."
10. **DO NOT** put your paper in a folder! These kill trees, waste resources and will not improve your grade. In fact, since your TA is probably a rabid environmentalist, it could HURT your grade.
11. **DO** type your report. No handwritten reports will be accepted. Do not wait until the last minute to print your report. "My printer broke down. . ." is NOT an acceptable excuse for handing in a late report. **Late papers will be docked two points per day.**
12. **DO NOT** wait 'til the last minute to *write* your report. Give yourself time to edit your work. Once you've finished your first draft, let it rest for a day or two, then GO BACK AND READ IT AGAIN or have a critical friend read it for you. You might be surprised at what a bit of editing will do for the quality (and grade) of your report.
13. And finally, please be sure you don't make these mistakes (or others like them)
    a. "**It's**" means "it is." The possessive form ("belonging to it)" is written "**its**."
    b. Data is the plural of datum. Data *are*; datum *is*.
    c. Effect is (usually) a noun. Affect is a verb. Know the difference.

IF YOU FOLLOW THESE RULES, YOU WILL BE WELL ON YOUR WAY TO A LONG AND HAPPY CAREER IN SCIENTIFIC WRITING.