Appendix III
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.

Go online or to the university library and peruse some of the scientific journals. Most scientific publications consist of a descriptive **title**, **abstract, introduction, methods, results, discussion** and **literature cited.** You will use this format for your own reports (including PowerPoint). This outline instructs you how to write each of the six components of a scientific paper or report. Label each component as shown below.

title

The title of your paper will be read by the most readers, and can determine whether the rest of your paper will be read. It should describe *specifically* the content of your paper, including the name of the organism being studied. Under the title, list your name, the date and your institutional affiliation.

abstract

The purpose of the abstract is to allow a reader to determine, with a very quick scan, the topic of your paper, your hypotheses, methods, and conclusions. Although the abstract appears *first*, it is written *last*. In one paragraph, offset from the rest of the paper, it provides 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 Do not cite literature references in the abstract.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. An investigator searching for information on a particular subject can look up and read abstracts--rather than an entire paper--to determine whether a paper is relevant to his/her own work. If it is, s/he can read the entire article.

introduction

This section can be written before you begin your experiment. In one to several paragraphs, give *specific* background information on your subject. Include a statement of purpose, the reasons for your experiment and why it is relevant and interesting. **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 introduction is the proper place for you to state your **question**, your **hypotheses**, and your **predictions**. Include a summary of expected results 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 methods section enables a reader to duplicate your experiment and test whether your results are reproducible. **Using past tense** (you are not writing a

cookbook), 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.") Describe your general experimental procedure only once, then note which procedures were changed for subsequent trials. If procedures are already published, then refer to your source, and don't exhaustively re-write them in your paper.

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. You are writing for an audience with some inkling of scientific knowledge, so consider that in your style and aim.

DO NOT INCLUDE ANY DATA OR CONCLUSIONS IN THIS SECTION!

results

Results are described in one to several **prose** paragraphs. *Never* give long lists of numbers in your prose text. List such results in tables or in figures. You must refer to each of your figures and tables somewhere in the text of your results. 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. More instructions can be found in Appendix IV.

Above all, be intellectually honest. Never 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 your predictions 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, telling the reader how they relate to your predictions and original hypotheses.

1. Link your results to your original hypotheses.
2. Which hypotheses are refuted? Which are not? 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—intellectually honest.
5. Discuss possible sources of error and how they might have affected your results, but don't get carried away. This should not be the main focus of your paper.

6. Compare your results to those of similar experiments published elsewhere.
7. Draw overall conclusions--give summary statements.
8. Discuss how your results suggest further hypotheses and experiments that could further elucidate the system you are studying.

This is your chance to show us your amazing capacity for creative, scientific thought. Whenever possible, refer to published literature on the subject (as in the Introduction), but don't be shy about giving your own insights.

If you do not give detailed, intelligent explanations for your outcomes, 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 instructor. Scientific literature.

Citation format differs somewhat from journal to journal, but the guidelines below are generally acceptable. If 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*., 2009).

(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.")

If you prefer to list your sources as footnotes, then simply mark each in numerical order, as necessary;

> Latex is a colloid consisting of a meshwork of mostly isoprene subunits (1). Certain types of nonpolar solvents are capable of disrupting the physical structure of latex (2).

Then, rather than listing the sources alphabetically in the literature cited section, list them in the order in which they are cited in your paper.

In some cases, you may wish to cite information you received verbally from an instructor or other authority. Such a 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:
All authors should be listed by last name and initials. If there are more than two authors, separate their names with commas, and place "and" before the last author. The year of publication comes after the authors' names, then the book's title (preferably italicized), publisher, city, and number of pages in the book.

For example, a book with one author:
Gould, S. J., 1983, *Hen's Teeth and Horse's Toes,* W. W. Norton, New York City, 413 p.

And for two or more authors:
Bell, C.R. and Taylor, B. J. 1982, *Florida Wildflowers,* Laurel Hill Press, Chapel Hill, NC, 308 p.

FOR A JOURNAL ARTICLE:
Schwalm, P. A., H. Starrett, P.H., and McDiarmid, R.W., 1977. Infrared reflectance in neo-tropical leaf-sitting frogs. Science 196: 1225-1227.

FOR INTERNET SOURCES:
Before you cite a source from the internet, be aware that most web sites are not appropriate as references for scientific works, as they have not been subject to peer review. However, many journals and scientific publications are available in online versions and these are perfectly acceptable. (Just avoid sites that end in .com or .net Sites ending in .edu and .gov may be more reliable, but if the information you are reading is not peer reviewed, then…*caveat lector*! To cite an internet source:

List the authors' last name(s) and initials (as above) and the date of publication/last modification. Follow the authors' names with the full title of the web article and then the title of the web journal or site in italics. (Be sure to include any version numbers, file numbers, etc. in parentheses; anything that helps your reader find your source is valuable. Finally, include the entire URL (preferably cut and pasted directly from your browser location window, to avoid typographical errors), followed by the date you last accessed the site, in parentheses.

Van de Perre, P, Jacobs, D., Sprecher-Goldberger, S., 1987, The latex condom, an efficient barrier against sexual transmission of AIDS-related viruses. *PubMed* 1(1): 49-52. http://www.ncbi.nlm.nih.gov/pubmed/3122790 (August 30, 2010)

The UM library has extensive internet resources at your disposal. Another good place to find scholarly articles online is GoogleScholar: www.googlescholar.com

don't make common mistakes!

1. **DO** use correct grammar and spelling. No, this might not be an English class. But we assume you already KNOW how to use the President's English 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.
   WRONG: "You then grab a flask and you heat it until it blows up real good."
   RIGHT: "I then grabbed a flask and heated it until it blowed up real good."
3. **DO** use the same tense (generally past 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.). Be dispassionate, and let the reader judge the data.
6. **DO NOT** state that your purpose is "to learn all about the phenomenon of...." **It is NOT.** Your purpose **IS** "to test the effect of X on Y" You are writing a scientific paper, not "What I did in school today."
7. **DO** write as though you had designed the experiment, which you did.
8. **DO** use your own words. Paraphrase cited sources. **Unless absolutely essential to convey some subtle point 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 hypothesis." WRONG: "The results kind of surprised me."
10. **DO NOT** put your paper in a folder! These 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 are docked two points per day.**
12. **DO NOT** wait 'til the last minute to *prepare* 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 of your work. Most of your reports will be a team effort, so it's even more important to be communicative, cooperative, and reliable so everyone has a good learning experience.
13. Finally, take the time and effort to learn proper grammar, word usage and spelling. There are many excellent online resources to help you, including this one:

http://www.grammarerrors.com/

So there really is no excuse for turning in a poorly written paper or PowerPoint presentation.