CHAPTER 6: A GUIDE TO WRITING SCIENTIFIC PAPERS[1]

This guide is intended to supply the student with a model for writing a paper on scientific research. Consider this guide to be an acceptable starting point. It will work well for any class taken in this Department of Biology.

Goals

The writing of scientific paper is based on several simple concepts. The main purpose of a scientific paper is to tell the reader why you did the experiment, what you did, how you did it, the results, and the significance of those results. The style emphasizes conciseness and clarity of language, so words must be chosen to say exactly what you mean them to say, with no tolerance for vagueness or "you know what I mean." The organization of a paper is logical, with rules for what goes into each section. Finally, factual material (results) and the interpretation of factual material (discussion) are clearly separated into different sections and never allowed to become confused. Remember these goals as you write a paper, and judge your own work by them before you complete it. In addition, a paper should be written in PAST TENSE as it is something that you have already done.

Sections of a Paper

Though individual papers will vary in some details, the basic arrangement of papers in this course is usually the following:

Title
Abstract
Body of the Paper:
    Introduction
    Materials and Methods
    Results
    Discussion
Literature Cited
Tables, Figures and Legends

Each section, other than the title page, should bear the heading for that section, e.g. “Materials and Methods." Papers should be paginated with the title page as page one and all subsequent pages numbered accordingly.

Title

◊ Title should appear at the top and be brief but should inform the reader of the subject (but usually not the results) of the work being reported. Be specific. "Franklin County Flora" is too broad for a project that is really "Differences in Flora at Different Elevations in Franklin County, Tennessee."

◊ The author's full name and the full names of all partners with whom data were shared (if any).

◊ The date.

[1]Adapted from a version written by Dr. Timothy Keith-Lucas and used with his permission.

◊ The pledge and signature of the author only.

Abstract

The abstract should be on the same page just after the title. The abstract is a brief (approximately 150-250 words) summary of the entire paper. The simplest way of writing an acceptable abstract is to summarize in turn each of the four major sections of the report (Introduction, Methods, Results, and Discussion) in, at most, two sentences each. Don't forget to include the results here.

Introduction

A typical (it varies) Introduction has three parts. First, in a brief paragraph, give general information relating to your topic. This should also include a general question or issue of interest. Note that this may be a general question about the way the world works, rather than a narrow question applicable only to one locality. You may be attempting to answer this question in a very narrow set of circumstances in one place, but your interest as a scientist is in broader questions about the world. It is most important, not just to the paper but to the success of the project in general, that this question or goal be clearly stated.

Having introduced a topic, now describe what is known about the topic prior to the beginning of your project. Typically, this part is a literature review, describing what others have found when they have studied similar issues in other locations. This section might include your logic for suspecting a particular result. Be sure to cite properly work which has already been published (see the Literature Cited section of this guide). Also, be sure to write this section as if it were written before the work began. Do not report results or reach conclusions here.

Finally, write a short paragraph telling the reader what your specific hypothesis is, and how you expect to test the hypothesis you have posed and reviewed above. "The hypothesis that flora composition will vary with slight changes in elevations will be tested by analyzing the flora at five elevations in Franklin County, Tennessee" could be the lead sentence in this section. Be brief, and leave the details for the Methods section.

Note the logic in the paper thus far. Introduce the reader to the topic, describe what is already known, and finally, state your hypothesis and how you intend to test it. Now the reader is ready to read the details of your work and will understand the intent behind your use of various methods.

Materials and Methods

In this section you need to describe your work in sufficient detail to allow the reader to replicate the study. That means that any detail that could influence your results needs to be included. An example would be the size of the sample taken or the season in which the study was performed, what solutions you used and what their concentrations were. The reader may need to read instruction manuals for equipment used, but they should know what equipment to use, volumes, weights, doses, settings, numbers of subjects and treatments, etc. Details that would not reasonably be expected to influence the results should be excluded. This

requires judgement. You must ask yourself whether a detail could influence the results, and you must describe an experiment clearly to someone who was not present when you were.

Describe the steps taken to complete the study. Avoid giving instructions ("Dip the pH meter in the sample.") when procedurally what happened was that the pH was measured. Again, include everything necessary to replicate the work, and nothing more. This is NOT to be written giving instructions as if it is a laboratory manual. Each step of the methodology should have its own paragraph and each paragraph should have a topic sentence, other sentences that are on that topic and give more details, and then a final sentence. A methods section that starts with "These are the methods I will use" and then goes on in one long paragraph is not acceptable.

Methods should include any formulas that you used for calculations. Include not only the formula with the variables [with all variables defined, e.g. M is the mass (g)] but also one sample of the formula with all the numbers substituted for the variables. Do this for all the formulas you use (except statistical formulas). Any statistics you use should be stated in the methods. For statistics, the formulas are generally well known, so you do not need to give statistical formulas, just state that you found the mean + S.E. (standard error or standard deviation – S.D. or whatever) and any test that you used to determine statistical differences between values (t-test, ANOVA, etc.).

Again, note the logic. Now you have described a specific experiment with which you hope to answer the question posed and reviewed in the Introduction.

Results

In the Results section describe what you got when you carried out the procedure just described in the Materials and Methods section. Report the results factually (no interpretation). Be quantitative (use the numbers), and leave your conclusions ("...because temperatures are lower at high elevations") for the Discussion.

The results will not be merely a compilation of tables and graphs. Although most of your results will appear in tables and figures (for example, graphs or drawings), a person reading the text of your Results section should understand the results of your study without having to study your figures and tables. ***Figures should support the text and supply details,*** but what happened should be clear from the text itself**.** ***Never, ever*****,** start a Results section with "The results are summarized in Figures 1 through 4." When used, figures and tables should clearly make your point, usually by comparing the results found under two or more conditions, and ***should be clearly labeled and cited in the text*** where appropriate. Avoid the temptation to pile in irrelevant figures.

Refer to figures and tables in the text of your Results by their numbers. You *do not* have to write "See Figure 1," just say something like "The osmotic concentration of the bodily fluids was higher in x than in y (Figure 1)." Figures and tables should be numbered separately, a series of numbers for figures and a series of numbers for tables. In addition, they should be **numbered in the order in which they are referred to in the text**. Never refer to Table 2 before you refer to Table 1. Renumber your tables if you need to!! Never

have a table or a figure to which you do not refer your reader!! You must make reference to all tables and figures.

Each table and each graph must be formatted properly. Tables should have a number and title above it (Table 1: Absorbance for pigment A at each wavelength tested.). Units should be found in Column titles (Wavelength (nm)). Any additional information such as abbreviations should be in a caption found below the table. Graphs or figures should also have a number and title, although these are often found below them as a caption (Figure 1. Absorption spectrum for pigment A.) Additional information, such as what each type of symbol or color of line means and any abbreviations should be given in a legend. In addition, **each axis must have a label**, and most parameters will have units.

Tables and figures should be found on separate sheets at the end of the paper. The table number and title with all needed information (such as abbreviations, etc.) should be on the same page as the table. The figure number should be on the same page as the figure. A list of figure legends can all be on one separate sheet at the end of the paper, or each figure legend can be on the same page as the figure. This is the way scientific journals require manuscripts to be formatted when submitted for publication.

Discussion

You have stated a hypothesis, described a specific experiment to address it, and reported the results of that experiment. Now it is time to discuss whether or not the data support the hypothesis. In the first paragraph you should start with a restatement of your hypothesis, why it was posed and whether or not your data support or do not support the hypothesis. It is best not to keep your reader guessing about whether or not the hypothesis was supported. In subsequent paragraphs, you should argue for your conclusion(s) with all the logic and data (from the results) that you can command.

NEVER say that you have proven ANYTHING in your paper. You have not. You have merely gathered evidence that either supports you hypothesis (fails to reject) or fails to support (rejects) your hypothesis.

You must also deal with alternative explanations for the results (such as having observed at different times of day in the two sites) and with weaknesses in your design, as in "The study would have been improved by a larger sample." If your conclusion is that your hypothesis was wrong, say so and why. In addition, data are never wrong (as long as there were proper controls and the methods were followed properly). They are just your data. Do not do a lot of data-bashing in your discussion. There is not a requirement that research turn out the way you expected it to. It is far more scientific to report your data accurately than to obtain conclusive results. It is OK to pose further hypotheses to be tested in the future.

Literature Cited

You are required to learn how to cite references, both in the text and at the end of the paper. The style presented here is the same as that used in the journal Ecology. Notice that it is different from styles used in English and other humanities courses. Refer to Chapter 7:

Literature Cited for instructions and examples of correct citations to be used in all assignments.

Note that you have come full circle. You started with a question and ended with the answer to it or with a hypothesis and ended either supporting or failing to support it. Thus is the logic of report writing.

Tables and Figures[2]

Tables and figures are elements of your work that allow you to summarize (tables) or graphically represent (figures) your data in a way that will give your reader a 'bottom line' understanding of your work. Each has it's own major parts with some important guidelines to remember.

Tables within a paper should be numbered (Table 1, Table 2 etc.) in the order that they appear in the paper. Number and title are located directly above the table. Titles should be unique for each table, and should tell the reader about the data. (Table 1 Index of similarity for diets of 3 sympatric salamander species.) Located above each column is a column heading, identifying the data in the column; usually just a word or short phrase. These are commonly the dependent variables. Row headings are found in the first column of the table. This column is also called the "stub". These headings are often the independent variables and are also just a short phrase. The body of the table, or the field, contains the data. Footnotes, denoted with a symbol and located directly beneath the table, should be used to clarify notations or other ambiguities in the table. (* Comparisons were made using the five most abundant prey items for each species.)

Figures are also numbered in the order in which they appear in a paper (Figure 1, Figure 2 etc.) and have a title as in tables. The caption consists of the Figure # and the title together, and is also a phrase or sentence fragment describing what the data show. (Figure 1. Five most abundant prey items for 3 sympatric species of salamander.) The caption is located below a figure. You'll use figures mostly to illustrate trends or proportions, but they also include photographs, drawings or other illustrations. Axes as well as legends should be clearly labeled including units for axes and symbols used in legends.

Tables and figures should be indirectly referenced in the text in which they are discussed using parentheses and the figure or table number (Table 2) or (Fig. or Figure 2).

Formatting

In scientific papers as in proposals, certain things need to be formatted very specifically. Please refer to Chapter 5 Research Proposal Guidelines for further format guidelines and examples.

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[2] CBE Style Manual Committee. CBE Style Manual: a guide for authors, editors, and publishers in the Biological sciences. 5th ed. Council of Biology Editors, Inc., Bethesda. 1983.