Guidelines for Scientific Writing

Scientific papers are the main mechanisms by which scientists communicate and a significant portion of a scientist's time is engaged in scientific writing. Because clarity and precision are so essential in scientific communication, the rules governing the writing of scientific papers are quite rigid. Unlike other forms of literature, there is little room in scientific writing for creativity; the creativity of science is in the doing, not the writing. The following is a brief guide for the preparation of a scientific paper.

A paper is typically organized into the following sections:

1. Title
2. Abstract
3. Introduction
4. Methods
5. Results
6. Discussion
7. Literature Cited

Title

The title should succinctly convey the focus of the study and the scope of the paper. Some authors prefer to give away the punch line in the title; for example, "Acclimation to Low Temperature Increases Metabolic Rate in Rainbow Trout, *Oncorhynchus mykiss*". Others prefer to make a more general statement; for example, "The Effects of Thermal Acclimation on Metabolic Rate of the Rainbow Trout, *Oncorhynchus mykiss*". Either form is acceptable.

As a rule, the genus and species of the organism studied should appear in the title for experimental laboratory studies. There are, however, some exceptions to this. For example, when the species name of an organism is common knowledge, the common name may be substituted (fruit fly for Drosophila melanogaster), or when a study is large in scope such as a field study which includes many species, none need be named. In any case, keep the title clear and short without sacrificing information.

Put your name and affiliation (school or other organization you are associated with when you wrote the paper) somewhere on the title page.

Abstract

This is a brief summary of the purpose and salient results of the study. It should provide a sentence or two of background for the study, a brief overview of the basic methods used, a summary of results, and a brief interpretation of the data. Usually this section includes the scientific name of the organisms that were studied. The exception to this rule may be if you have done a field study which looked at many different species. In this case, you may name only those species that figure prominently

in your results and discussion. No table or figures are put here, and no references are cited. This section is used by the reader to determine whether or not it would be useful or interesting to read the entire paper, but as an author, don't try to entice the reader with mystery or cleverness. Simply state what you did, what you found, and what it means. The abstract should be less than one double-spaced page in your draft, but **single-spaced** in your final paper. In general, abstracts consist of only one paragraph. The abstract is placed on a separate page in your final version. For a published work, this part of the paper would be reprinted in Biological Abstracts and be posted on the electronic abstracting services such as Medline or FirstSearch. At the end of the abstract, list a few key words or phrases under which you think the paper should be listed by the abstracting and referencing services.

Introduction

The introduction is where you place your study in the context of the field as a whole, and also provide the rationale for the study. This is best done by a sort of sophisticated story-telling. Use the work of others that have published on your topic before you to set the stage. It is not necessary to cite every article written that relates to your study, but you should have enough citations to develop a reasonable rationale and provide the background leading to the hypotheses you have tested. At the end, state your hypotheses clearly, and outline the predictions of the hypotheses and the expected results if your hypotheses are valid. State implicitly here the significance of the study you have done. A VERY simplistic example follows:

Previous studies (Finhead and Fishead, 1988) on the metabolic rates of rainbow trout, *Oncorhynchus mykiss*, have shown that short-term exposure to low temperatures results in decreased metabolic rates. Similar results were obtained using crustaceans (Crabhead, 1989) and amphibians (Toadface, 1990). However, little is known about how this decrease in metabolic rate is modified by the thermal history of the animal. Croaker (1992) has shown that a two-week acclimation to 10'C has no effect on the metabolic rate of frogs at any temperature of measurement, whereas Claw and Jones (1988) showed that prior exposure to low temperatures for 5 weeks raised the metabolic rates of lobsters at low temperatures of measurement (for review, see Smith, 1994). We tested the effect of thermal acclimation for prolonged periods (6 weeks) on the metabolic rates of rainbow trout measured at both low and high temperatures. Any ability to compensate for low environmental temperatures, such as those experienced by the animal during the cold seasons of the year in the natural environment, would be manifest in the higher metabolic rates of cold-acclimated animals when compared to warm-acclimated conspecifics.

Methods

This is where you describe how you went about testing your hypotheses. You must provide enough information that another investigator could duplicate your study simply by reading your description. Chances are your study will not be duplicated exactly, but may be modified by another

investigator in order to answer related questions or pose similar but not identical hypotheses. Certain procedures need not be described exhaustively; i.e., routine lab procedures (mixing solutions, weighing materials, scrubbing of rocks, transfer of samples from the net to basins, etc.), or those described in detail in other papers. Simply cite the source of your protocol, describing in detail any modifications you may have made.

You *should* include locations and site descriptions for field studies, the numbers of organisms you used, and the statistical methods employed. Some journals allow authors to employ a separate section to describe field sites, called *Study Site*; it usually is placed before the Methods section. Also, any materials that are not routinely available or that may differ in quality from one supplier to another should be mentioned followed by the name of the supplier.

Results

In the Results, simply state what you found, without interpretation or elaboration. Your results should be logically organized into tables, figures, or both. Every table and figure should be mentioned in the text, in order of appearance. The text should describe what kinds of information are in each table and figure, the most salient features of the data presented, and/or the features you would like to call to the attention of the reader. There is no need to point out every datum, but do point out trends you may want to focus on later in the Discussion portion of the paper.

Raw data is almost never included in a scientific paper. Data is summarized in some form; for example, means are reported, not individual observations, or the data are plotted in a manner which illustrates the trends you want to emphasize. Include descriptive and analytical statistics; i.e., standard deviations (or Standard errors of the means, SE), the results of t-tests or analyses of variance (ANOVA). It is sufficient to indicate where statistical significance occurred and the confidence level. No need to provide all of your calculations. Some complex calculations may be provided in an Appendix at the end of the paper.

Include figure legends below graphs and table legends above tables. Number your figures Fig. 1, Fig. 2, etc., and your tables Table 1, Table 2, etc. The legends should include a title (for example: Fig. 1. Metabolic rates of rainbow trout at different temperatures.), and a sentence or two of explanation (i.e., Metabolic rates of n=6 fish were measured at both 5 and 20'C. Measurements were made using closed-chamber respirometry. All animals were acclimated to 10'C for 6 weeks prior to measurements.). Do not use the terms Graph or Chart in the titles. Graphs (as well as line drawings, photographs and maps) are Figures and charts are called Tables.

Discussion

In this section, interpret your results and state your conclusions in the light of your original hypothesis. Examine your results in the context of other published studies (with appropriate citations).

Consider here any sources of error or differences in protocol that might cause your results to differ from other published data, or point out support other data may give to your interpretations. Refer to the tables and graphs in your Results section to make your points if necessary. You may even want to briefly re-state a few of your results if it helps your interpretive argument. Be concise, be accurate, but be persuasive in this section. Convince the reader that your interpretation is the correct one.

Literature Cited

This final section of the paper is a list of the sources that were cited in the paper. The list is arranged alphabetically by last name of the first author of the source book or paper. **DO NOT** include other sources that were not cited, even if they are relevant and you read them from beginning to end. **ONLY** list those you have cited in the text. Remember, any ideas that are not your own **MUST** be credited to the author. Scientific papers do not use footnotes. After the statement of an idea in the text, put the name(s) of the author(s) of the source paper followed by the year that the source paper was published in parentheses (Finhead and Fishead, 1978). If there are three or more authors, use *et al;* for example (Finhead *et al.* 1979). Provide the full citation for the source in Literature Cited, at the end of the paper.

A standard format is as follows, but may differ from journal to journal:

Finhead, A. G. and B. B. Fishead. 1978. The effect of temperature on the metabolic rate of thermally acclimated rainbow trout, *Oncorhynchus mykiss*. J. Exp. Biol. 97: 512-514.

Check the Literature Cited in the papers you read to get an idea of how this is done for single author books, edited books, government documents, and other types of sources.

Other Hints

1. Underline or *italicize* scientific names and other Latin usage, such as *et al.* and *e.g.* It is not necessary for names of family or other more inclusive taxa to be italicized. In general, enclose the scientific name in parentheses following the first mention of the common name. Thereafter, use the common name except for species where the scientific name is more often used or for species which have no accepted common name. Do not capitalize common names except when the word begins a sentence or the common name includes a proper noun (e.g. Blanding's turtle, New York fern). If a different species of a genus previously referred to is mentioned, use the initial of the genus with the specific name (e.g. *Rana clamitans* and *R. sylvatica* both eat crickets…). If the specific name is unknown, list the genus name followed by sp. (*e.g.* We observed a small garter snake (*Thamnophis* sp.) living in the basement). If the genus name may refer to several species, use the genus name followed by spp. (*e.g. Clemmys* spp. are all omnivorous). Do not underline or italicize sp. or spp.
2. Clearly document units of measurement in your paper (i.e., Metabolic rate [ml/mg body weight/min]).

3. Avoid writing in the first person. There are times when this is okay, such as when describing what you did, but never use modifying phrases like “I think...” or “We feel...” If you are expressing opinion, it is best to say something like “It appears that…” or “The data are consistent with…”
4. Refer to other peoples’ published work in the past tense; refer to your work in the current paper in the present tense.
5. Read the scientific literature. That is clearly the best way to get a feel for writing scientifically. Remember, scientists are among the worst writers in the world. It is a difficult task to write with the fluidity and clarity that makes a paper a pleasure to read, and yet maintain the rigid ground rules of scientific writing. This skill won’t come easily, but it is well worth developing.
6. Double-space the final paper and all drafts (except the abstract, which is single-spaced).

Two useful books about scientific writing designed for students:

McMillan, V.E. 2001. Writing papers in the biological sciences. 3rd Edition. Bedford/St. Martin’s Press, Boston and New York. 207 p.

Pechenik, J.A. 2001. A short guide to writing about biology. 4th Edition. Addison-Wesley Educational Publishers, New York. 318 p.