A Guide to Writing in the Biological Sciences

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The author is not known. Adaptations by Dieter Ebert and Mathias Kölliker

A well-written scientific paper explains the scientist's motivation for doing an experiment, the experimental design and execution, and the meaning of the results. Scientific papers are written in a style that is exceedingly clear, concise and focused. Their purpose is to inform an audience of other scientists about an important issue and to document the particular approach they used to investigate that issue. Please do not think that good English is not critical in science writing. The concise writing style necessitates efficient usage of the language, which is a major challenge in modern scientific writing. If English is not your first language, then proofreading by a native-speaker might be helpful.

If you have read scientific papers, you will have noticed that a standard format is frequently used. This format allows a researcher to present information clearly and concisely. While the overall structure with the main sections (see below) is standard, the details of the formats are usually defined by the journal where a paper is submitted.

General organization

The following sections should be included in your paper:

1. Title
2. Authors + Affiliations
3. Abstract
4. Introduction
5. Methods
6. Results
7. Discussion
8. Literature

Sub-structuring the main sections by use of sub-headings is possible if this enhances the clarity. It is important to understand the differences between sections and to put information in the appropriate location. Students frequently begin discussing their results in the Results section or present some of their results in the Discussion section. This should be avoided. Reading scientific papers (such as the articles you will use as your references for the Introduction and Discussion) will give you good ideas and guidance as well. After all, these are peer-reviewed and published scientific papers, and they can serve as useful models for your own writing. However, it is crucial to avoid plagiarism, that is, copying text literally from other published work. Plagiarism is one of the main frauds encountered in scientific practice (see also lecture on “Good scientific practice”). One useful way to avoid making errors in this regard is to read a section from your source, then restate in writing what you remember of the main points using your own words. You would then cite the source of that information in the text. For excellent guidance on this topic, consult V.E. McMillan's 1997 book, Writing Papers in the Biological Sciences. St. Martin's Press, N.Y., or other books on scientific paper writing, for further advice.

Abstract

An abstract is a shortened version of the paper and should contain all information necessary for the reader to determine:

1. what the objectives of the study were;
2. how the study was done;
3. what results were obtained;
4. and the significance of the results.

Frequently, readers of a scientific journal will only read the abstract, choosing to read at length those papers that are most interesting to them. For this reason, and because abstracts are frequently made available to scientists by various computer abstracting services, this section should be written carefully and succinctly to have the greatest impact in as few words as possible. Although it appears as the first section in a paper, most scientists write the abstract section last.
Introduction

Why is this study of scientific interest and what is your objective?

This section introduces the topic of the reported research, discusses the results and conclusions of previously published studies, to help explain why the current study is of scientific interest. The Introduction is organized to move from general information to specific information. Take care not to go too far afield in providing background information; limit the introduction to studies that relate directly to the present study. Emphasize your specific contribution to the topic.

The last paragraph of the introduction should be a statement of objectives and a statement of hypotheses for the reported research. This will be a good transition to the next section, Methods, in which you will explain how you proceeded to meet your objectives and test your hypotheses. For example, you might write the following:

"Our objective was to determine if the relationship between legumes and nitrogen-fixing bacteria is species-specific. We hypothesized that legumes would grow best when infected by the same Rhizobium species that it occurs with in the field."

How to Cite Sources in the Introduction Section

It is important to cite sources in the introduction section of your paper as evidence of the claims you are making. There are ways of citing sources in the text so that the reader can find the full reference in the literature section at the end of the paper, yet the flow of the reading is not badly interrupted. There are general conventions for how this should be done. Check out published papers for how this might be done. Format details for in-text citations are usually also given by the journal where you plan to submit your paper.

Methods

This section provides all the methodological details necessary for another scientist to duplicate your work. It should be a narrative of the steps you took in your experiment or study, not a list of instructions such as you might find in a cookbook. You should assume that the other scientist has the same basic skills that you have, but does not know the specific details of your experiment. An important part of writing a scientific paper is deciding what bits of information needs to be given in detail. Do not quote or cite your laboratory manual, only published work! In the last paragraph, provide a brief description of statistical tests you used (statistics are methods!). Be sure not to include basic statistical background and information, though. Scientists are familiar with the general principles of statistics and know all about null hypotheses and when to reject them. See the Results section for more information on statistics.

Results

This section presents the results of the experiment but does not attempt to interpret their meaning. As with the Methods section, the trick to writing a good Results section is knowing what information to include or exclude. You will not present the raw data that you collected, but rather you will summarize the data with text, tables and/or figures. Use the text of the paper to state the results of your study, then refer the reader to a table or figure where they can see the statistically summarized data for themselves. For example you may write:

"Nitrogen fertilizer significantly increased soy bean total biomass ($t_{15} = 2.95, p = 0.01$) regardless of the presence or absence of Rhizobium ($t_{15} = 0.86, p = 0.40$) (Fig. 1)."

The sentence above is well written because: (i) the result of adding nitrogen is stated concisely, (ii) the word significantly is accompanied by the test statistics ($t_{15} = 2.13$) and the statistical probability level ($p=0.05$), (iii) the scientific name Rhizobium is italicized, and (iv) the reader is referred to a figure where the data to support the statement is graphically displayed. Note that the measurement (total biomass, in this case) is mentioned. You must explicitly state the measure you are using. Avoid redundant presentation of the same data in both a table and a figure. Tables and figures are meant to summarize or visually illustrate the most important results, but they do not replace any text that describes the findings. The result section is a fluent text section like the other parts of a paper.

Each table and figure has several lines of text in the legend (or caption) that explain the information that is being presented; this is, they are made to stand alone. A table's legend appears above it, while the legend for a figure appears below the figure.
If your table includes the results of a statistical analysis, be sure to provide the information necessary for the reader to properly evaluate the analysis (test statistic (F/t-values), probability levels, degrees of freedom, sample size, etc.).

Additional tips on the Results section:
- Number tables and figures separately beginning with 1 (i.e. Table 1, Table 2, Figure 1, etc.).
- You must refer in the text to each figure or table you include in your paper.
- Tables generally should report summary-level data, such as means ± standard deviations, rather than all your raw data.
- Only use a figure (graph) when the data lend themselves to a good visual representation. Avoid using figures that show too many variables or trends at once, because they can be hard to understand.

Discussion
In this section, you are free to explain what the results mean or why they differ from what other workers have found. You should interpret your results in light of other published results, by adding additional information from sources you cited in the Introduction section as well as by introducing new sources. Make sure you provide accurate citations. Relate your discussion back to the objectives and questions you raised in the Introduction section. However, do not simply re-state the objectives. Make statements that synthesize all the evidence (including previous work and the current work). Do not make statements that are too broad: it is unlikely, for example, that through one Rhizobium-legume experiment, you will discover that there is no symbiosis between the two organisms. Limit your conclusions to those that your data can actually support, such as "We did not find a significant effect of Rhizobium inoculate on soybean biomass in this experiment." You can then proceed to speculate on why this occurred and whether you expected this to occur, based on other workers' findings.

Suggest future directions for research, new methods, explanations for deviations from previously published results, etc. If necessary, note problems with the methods and explain anomalies in the data. Do not simply list the problems but provide thoughtful discussion about the implications of the errors in terms of your conclusions.

How to Cite Sources in the Discussion Section
It is important to cite sources in the discussion section of your paper as evidence of the claims you are making. There are ways of citing sources in the text so that the reader can find the full reference in the literature cited section at the end of the paper, yet the flow of the reading is not badly interrupted. Check out published papers to check out how this might be done.

Literature Cited / References
This is the last section of the paper. Here you should provide an alphabetical listing of all the published work you cited in the text of the paper. This does not mean every article you found in your research; only include the works you actually cited in the text of your paper. For papers published in journals you must provide the authors, year, title, journal name, volume number, and page numbers. For books you need the authors, publication year, title, publisher, and place of publication. The details of the format of the list of cited literature depends on the journal in which you are planning to submit your paper. Journals define the citation and reference list formats in their "guidelines for authors".

Here are hypothetical examples of the format used in the journal Ecology: