How to Write & Publish a Scientific Paper

All information below is taken–in pieces–from Robert Day's "How to Write & Publish a Scientific Paper", (1998) 5th ed. I've compiled the most relevant points here, from ~230 pages of text in the original. [There is a 2016 version (8th ed.), but the 1998 is available electronically through the Cornell library.]

Preface

The goal of scientific research is publication. Scientists, starting as graduate students, are measured primarily not by their dexterity in laboratory manipulations, not by their innate knowledge of either broad or narrow scientific subjects, and certainly not by their wit or charm; they are measured, and become known (or remain unknown) by their publications.

A scientific paper is organized to meet the needs of valid publication. It is, or should be, highly stylized, with distinctive and clearly evident component parts.

What is Scientific Writing?

Scientific writing is the transmission of a clear signal to a recipient. The words of the signal should be as clear and simple and well-ordered as possible. In scientific writing, there is little need for ornamentation. The flowery literary embellishments—the metaphors, the similes, the idiomatic expressions—are very likely to cause confusion and should seldom be used in writing research papers. Science is simply too important to be communicated in anything other than words of certain meaning. Many kinds of writing are designed for entertainment. Scientific writing has a different purpose: to communicate new scientific findings. **Scientific writing should be as clear and simple as possible.**

In short, I take the position that the preparation of a scientific paper has less to do with literary skill than with organization. **A scientific paper is not literature.** The preparer of a scientific paper is not an author in the literary sense.

Thus, sufficient information must be presented so that potential users of the data can (1) assess observations, (2) repeat experiments, and (3) evaluate intellectual processes. (Are the author's conclusions justified by the data?)

Importance of the Title

In preparing a title for a paper, the author would do well to remember one salient fact: That title will be read by thousands of people. **Perhaps few people, if any, will read the entire paper, but many people will read the title**, either in the original journal or in one of the secondary (abstracting and indexing) publications. Therefore, all words in the title should be chosen with great care, and their association with one another must be carefully managed. Perhaps the most common error in defective titles, and certainly the most damaging in terms of comprehension, is faulty syntax (word order). What is a good title? I define it as the fewest possible words that adequately describe the contents of the paper. Remember that the indexing and abstracting services depend heavily on the accuracy of the title, as do the many individual computerized literature-retrieval systems in use today. An improperly titled paper may be virtually lost and never reach its intended audience.

Abstract

An Abstract should be viewed as a miniversion of the paper. **The Abstract should provide a brief summary of each of the main sections of the paper: Introduction, Materials and Methods, Results, and Discussion.** "A well-prepared abstract enables readers to identify the basic content of a document quickly and accurately, to determine its relevance to their interests, and thus to decide whether they need to read the document in its entirety" (American National Standards Institute, 1979b). The Abstract should not exceed 250 words and should be designed to define clearly what is dealt with in the paper.

The Abstract should (1) state the principal objectives and scope of the investigation, (2) describe the methods employed, (3) summarize the results, and (4) state the principal conclusions. The importance of the conclusions is indicated by the fact that they are often given three times: once in the Abstract, again in the Introduction, and again (in more detail probably) in the Discussion. **Most or all of the Abstract should be written in the past tense, because it refers to work done.** The Abstract should never give any information or conclusion that is not stated in the paper. References to the literature must not be cited in the Abstract (except in rare instances, such as modification of a previously published method).

An effective discussion of the various uses and types of abstracts was provided by McGirr (1973), whose conclusions are well worth repeating: **"When writing the abstract, remember that it will be published by itself, and should be self-contained."**

The language should be familiar to the potential reader. Omit obscure abbreviations and acronyms. Write the paper before you write the abstract, if at all possible. When writing the Abstract, examine every word carefully. If you can tell your story in 100 words, do not use 200. Economically and scientifically, it doesn't make sense to waste words.

Introduction

Suggested rules for a good Introduction are as follows: (1) The Introduction should present first, with all possible clarity, the nature and scope of the problem investigated. (2) It should review the pertinent literature to orient the reader. (3) It should state the method of the investigation. If deemed necessary, the reasons for the choice of a particular method should be stated. (4) It should state the principal results of the investigation. (5) It should state the principal conclusion(s) suggested by the results.
Do not keep the reader in suspense; let the reader follow the development of the evidence.

Many authors, especially beginning authors, make the mistake (and it is a mistake) of holding back their most important findings until late in the paper. In extreme cases, authors have sometimes omitted important findings from the Abstract, presumably in the hope of building suspense while proceeding to a well concealed, dramatic climax. However, this is a silly gambit that, among knowledgeable scientists, goes over like a double negative at a grammarians' picnic. Basically, the problem with the surprise ending is that the readers become bored and stop reading long before they get to the punch line.
"Reading a scientific article isn't the same as reading a detective story. We want to know from the start that the butler did it" (Ratnoff, 1981).

In the Introduction you should have a "hook" to gain the reader's attention. Why did you choose that subject, and why is it important?

Materials and Methods

Now, in Materials and Methods, you must give the full details. Most of this section should be written in the past tense. **The main purpose of the Materials and Methods section is to describe (and if necessary defend) the experimental design and then provide enough detail so that a competent worker can repeat the experiments.**

Headings

The Materials and Methods section usually has subheadings. When possible, construct subheadings that "match" those to be used in Results. The writing of both sections will be easier if you strive for internal consistency, and the reader will be able to grasp quickly the relationship of a particular methodology to the related Results.

Statistical analyses are often necessary, but you should feature and discuss the data, not the statistics. Generally, a lengthy description of statistical methods indicates that the writer has recently acquired this information and believes that the readers need similar enlightenment. Ordinary statistical methods should be used without comment; advanced or unusual methods may require a literature citation.

Results

There are usually two ingredients of the Results section. First, you should give some kind of overall description of the experiments, **providing the "big picture**," without, however, repeating the experimental details previously provided in Materials and Methods. Second, you should **present the data**. Your results should be presented in the past tense.

The Results need to be clearly and simply stated because it is the Results that constitute the new knowledge that you are contributing to the world. The earlier parts of the paper (Introduction, Materials and Methods) are designed to tell why and how you got the Results; the later part of the paper (Discussion) is designed to tell what they mean. Obviously, therefore, the whole paper must stand or fall on the basis of the Results. Thus, the Results must be presented with crystal clarity.

Discussion

The Discussion is harder to define than the other sections. Thus, **it is usually the hardest section to write.** Many papers are rejected by journal editors because of a faulty Discussion, even though the data of the paper might be both valid and interesting. Even more likely, the true meaning of the data may be completely obscured by the interpretation presented in the Discussion, again resulting in rejection.

Components of the Discussion

1. Try to present the principles, relationships, and generalizations shown by the Results. And bear in mind, **in a good Discussion, you discuss—you do not recapitulate—the Results**.
2. Point out any exceptions or any lack of correlation and define unsettled points. Never take the high-risk alternative of trying to cover up or fudge data that do not quite fit.
3. Show how your results and interpretations agree (or contrast) with previously published work.
4. Don't be shy; discuss the theoretical implications of your work, as well as any possible practical applications.
5. State your conclusions as clearly as possible.
6. Summarize your evidence for each conclusion.

Significance of the Paper

Too often, the significance of the results is not discussed or not discussed adequately. If the reader of a paper finds himself or herself asking "So what?" after reading the Discussion, the chances are that the author became so engrossed with the trees (the data) that he or she didn't really notice how much sunshine had appeared in the forest. **The Discussion should end with a short summary or conclusion regarding the significance of the work.**

Defining Scientific Truth

In showing the relationships among observed facts, you do not need to reach cosmic conclusions. Seldom will you be able to illuminate the whole truth; more often, the best you can do is shine a spotlight on one area of the truth. Your one area of truth can be illuminated by your data; if you extrapolate to a bigger picture than that shown by your data, you may appear foolish to the point that even your data-supported conclusions are cast into doubt.

Citation in the Text

I find it depressing that many authors use slipshod methods in citing the literature. (I never stay depressed long—my attention span is too short.) Even worse is the nasty habit some authors have of insulting the authors of previous studies. It is probably all right to say "Smith (1997) did not study. . . ." But it is not all right to say "Smith (1997) totally overlooked. . . ." or "Smith (1997) ignored. . . ."

Some authors get into the habit of putting all citations at the end of sentences. This is wrong.
The reference should be placed at that point in the sentence to which it applies.

Michaelson (1990) gave this good example:
We have examined a digital method of spread-spectrum modulation for multiple-access satellite communication and for digital mobile radiotelephony.[1,2]

Note how much clearer the citations become when the sentence is recast as follows:
We have examined a digital method of spread-spectrum modulation for use with Smith's development of multiple-access communication[1] and with Brown's technique of digital mobile radiotelephony.[2]

Tables and Graphs

When to Illustrate

Basically, graphs are pictorial tables. The point is this. **Certain types of data, particularly the sparse type or the type that is monotonously repetitive, do not need to be brought together in either a table or a graph.** The facts are still the same: The cost of preparing and printing an illustration is high, and we should consider illustrating our data only if the result is a real service to the reader. This bears repeating because many authors, especially those who are still beginners, think that a table, graph, or chart somehow adds importance to the data. Thus, in the search for credibility, there is a tendency to convert a few data elements into an impressive-looking graph or table. My advice is don't do it. Your more experienced peers and most journal editors will not be fooled.

When to Use Graphs

Graphs are very similar to tables as a means of presenting data in an organized way. In fact, the results of many experiments can be presented either as tables or as graphs. How do we decide which is

preferable? This is often a difficult decision. A good rule might be this: If the data show pronounced trends, making an interesting picture, use a graph. If the numbers just sit there, with no exciting trend in evidence, a table should be satisfactory (and certainly easier and cheaper for you to prepare). Tables are also preferred for presenting exact numbers.

If there is space in the graph itself, use it to present the key to the symbols.

Choosing the Right Graph Type
The graphic format you choose should clarify the numerical information for the reader by allowing easy comparisons and by conveying the concepts covered in the associated text.

Most graphs used for scientific descriptions are based on the following types of configurations:

- Bar charts to compare relative proportions and amounts and show trends and changes over time.
- Tables make comparisons of proportions and amounts.
- Pie charts illustrate proportions and show changes over time.
- Line graphs show trends and changes over time.
- Multi-plot charts display correlations between events. Multi-plot charts can be constructed in the following ways: (1) by combining line and vertical bar data; (2) by using a double vertical bar graph, with each bar representing two data sets, one on the bottom and one on top; (3) by using a line chart with individual lines representing each data variable; or (4) by using a scatter plot with two distributions.

Final Review

After the manuscript has been input, you will be wise to do two things. First, read it yourself. You would be surprised how many manuscripts are submitted to journals without being proofread. Second, ask one or more of your colleagues to read your manuscript before you submit it to a journal. It may well be that the meaning of one or more parts of your paper is completely unclear to your colleague. Of course, this may be because your colleague is dense, but it is just possible that this portion of your manuscript is not as clear as it could be.

Avoid jargon
Jargon does not necessarily involve the use of specialized words. Faced with a choice of two words, the jargonist always selects the longer one. The jargonist really gets his jollies, however, by turning short, simple statements into a long string of words.

Mumblespeak and Other Sins
The most common type of verbosity that afflicts authors is jargon. This syndrome is characterized, in extreme cases, by the total omission of one-syllable words. Writers with this affliction never use anything— they utilize. They never do—they perform. They never start—they initiate. They never end—they finalize (or terminate). They never make—they fabricate. They use initial for first, ultimate for last, prior to for before, subsequent to for after, militate against for prohibit, sufficient for enough, and plethora for too much.

Oral Presentations

The best way (in my opinion) to organize a paper for oral presentation is to proceed in the same logical pathway that one usually does in writing a paper, **starting with "what was the problem?" and ending with "what is the solution**?" However, it is important to remember that oral presentation of a paper does not constitute publication, and therefore different rules apply. The greatest distinction is that the published paper must contain the full experimental protocol, so that the experiments can be repeated. The oral presentation, however, need not and should not contain all of the experimental detail, unless by chance you have been called upon to administer a soporific at a meeting of insomniacs. Extensive citation of the literature is also undesirable in an oral presentation.

Presentation of the Paper

Most oral presentations are short (with a limit of 10 minutes at many meetings). Thus, even the theoretical content must be trimmed down relative to that of a written paper. No matter how well organized, too many ideas too quickly presented will be confusing. **You should stick to your most important point or result and stress that.**

The Audience

The presentation of a paper at a scientific meeting is a two-way process. Almost certainly, the audience for an oral presentation will be more diverse than the readership of a scientific paper. Therefore, the oral presentation should be pitched at a more general level than would be a written paper. Avoid technical detail. Define terms. Explain difficult concepts. A bit of redundancy can be very helpful.

The best part of an oral presentation is often the question-and-answer period. During this time, members of the audience have the option, if not the obligation, of raising questions not covered by the speakers, and of briefly presenting ideas or data that confirm or contrast with those presented by the speaker. Such questions and comments should be stated courteously and professionally.

Day's Personal Summary

If we view knowledge as the house we live in, scientific knowledge will tell us how to construct our house. But we need artistic knowledge to make our house beautiful, and we need humanistic knowledge so that we can understand and appreciate life within our house. If we view a scientific paper as the culmination of scientific research, which it is, we can, if we but try, make it more beautiful and more understandable; we can do this by enriching our scientific knowledge with a bit of the arts and humanities. A well-written scientific paper is the product of a well-trained scientist, yes; but the scientist capable of writing a really good paper is usually also a cultured man or woman. Students of the sciences must not content themselves with study of the sciences alone; science will be more meaningful if studied against a background of other knowledge. Especially, students must learn how to write, because science demands written expression. To learn to write, you must learn to read. **To learn to write well, you should read good writing**. Read your professional journals, yes, but also read some real literature.

What I have said in this book is this: Scientific research is not complete until the results have been published. Therefore, a scientific paper is an essential part of the research process. Therefore, the writing of an accurate, understandable paper is just as important as the research itself. Therefore, the words in the paper should be weighed as carefully as the reagents in the laboratory. Therefore, the scientist must know how to use words. Therefore, the education of a scientist is not complete until the ability to publish has been established.