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Guidelines for writing a scientific paper

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Introduction

Research—no matter how well performed—is of little use if people are not made aware of it. The usual way of making the results known is to publish a report of the study in a learned journal. Unfortunately, this is not always as easy as it may appear, particularly for researchers in developing countries writing in a language that is not their own. Many journals, especially the more prestigious, receive many more papers than they can publish, and the journal editor may make a preliminary selection even before sending them out for peer review. In an ideal world, perhaps, papers would be judged solely on their scientific content. In the real world, however, editors and reviewers are unlikely to have the time or the patience to read a badly prepared, poorly written or messy manuscript. The decision to publish may thus be based, not solely on the quality of the research, but also on a number of other factors—the structure of the report, the quality of the illustrations, the clarity of the writing, etc. Researchers need to be aware of these factors, and to prepare their reports accordingly.

This short course provides general guidance on writing a scientific research paper for publication in a learned journal. Advice is given on how to structure the report, how to write an abstract, and how to prepare tables, figures, and references. A general discussion is included on selecting the most appropriate journal, responding to reviewers and making revisions, and checking proofs.

The material presented in this course is largely based on the following publications:

DAY RA. *How to write and publish a scientific paper, 3rd ed.* Phoenix, AZ, Oryx Press, 1988.
HUTH EJ. *How to write and publish papers in the medical sciences, 2nd ed.* Baltimore, MD, Williams and Wilkins, 1990.
O'CONNOR M, WOODFORD FP. *Writing scientific papers in English.* Tunbridge Wells, Pitman, 1977.
A guide to writing for the United Nations. New York, United Nations, 1984.
SCIENTIFIC ILLUSTRATION COMMITTEE OF THE COUNCIL OF BIOLOGY EDITORS. *Illustrating science: standards for publication.* Bethesda, MD, Council of Biology Editors, 1982.

THE PARTS OF A RESEARCH ARTICLE

This section considers the different parts of a research article in turn, in the order in which they would normally appear. This does not necessarily correspond to the order in which they will be written.

Title

The title is the first thing that readers see when scanning a journal or searching an abstracting or indexing service. It is often what prompts the reader to read the article. The title should thus be chosen with great care. A good title can be defined as the fewest possible words that adequately describe the contents of the paper. A number of common faults are listed below:

—the title is too short
—the title is too long
—the title is not specific
—the title is ambiguous
—the syntax is poor
—the title contains abbreviations or jargon.

Authors

Deciding on who should be listed as authors is usually the easiest part of writing a paper. A few points are worth bearing in mind, however.

The list of authors should include those—and only those—who actively contributed to the design and execution of the experiments. Each author should have participated sufficiently to take public responsibility for the content.

The authors should normally be listed in order of importance to the experiments.

The address of each author should be clearly given.

There should be a clear indication of which author should receive correspondence related to the paper, including requests for reprints.

Abstract

An abstract is a miniature version of the paper. It should provide a brief summary of each of the main sections of the paper—Introduction, Materials and Methods, Results, Discussion. It should normally not exceed 250 words in length and should be constructed as a single paragraph. The following guidelines should be followed:

The abstract should be written in the past tense.
It should not contain abbreviations or acronyms, unless absolutely necessary.
It should not contain anything that is not in the paper.
It should be self-contained, e.g. it should not contain any references to the literature or to figures and tables in the body of the paper.
The language should be simple and clear.

Introduction

The first section of the paper—the introduction—should:

—give the reader some background information on the study (the rationale);
—state the purpose of the study.

It is not necessary to give an extensive literature review of the subject under study. The aim is to enable the reader to understand what question you have attempted to answer and why, and to appreciate the significance of your findings. Do not include here any results or conclusions.

Materials and methods

This section of the paper should describe what you did. The key here is that you should include sufficient detail to enable other workers in the field to reproduce your experiments. You should pay special attention to this section, since the credibility of your results depends to a large extent on the credibility of your method.

Materials

Give exact technical specifications of the materials used.
Do not use proprietary names unless the properties of a particular proprietary product were important to the experiment.
Give the genus, species and strain of any animals, plants, etc. used in the study.

Study subjects

Describe how you selected the subjects studied, i.e. inclusion and exclusion criteria.
Give details of all relevant characteristics of the study subjects and of any control subjects.
If human subjects are involved, give details of informed consent procedures.

Methods

Describe what you did. If you used a well established method, it may be necessary simply to mention it by name, or to give an appropriate reference. If your study method was new, however, you should describe it in sufficient detail to permit other workers in the field to replicate it.

Statistical analysis

Describe what statistical methods you used. You should give enough detail to enable a knowledgeable reader with access to your data to verify the reported results. Discuss the eligibility of the experimental subjects and give details of randomization or blinding of observations.

In general:

—*be precise*. If drugs were given, specify the dosages and the routes of administration. Identify precisely all drugs and chemicals used. If something was heated, specify the temperature.

—*be concise*. Try to avoid long complicated sentences. Clarity of ideas is essential for clarity of writing, and will greatly help the reader. The methods and materials section lends itself to short simple sentences, conveying one piece of information at a time.

Results

This section is perhaps the most important of the whole paper, and is likely to be of most interest to readers. The results should be stated as clearly and simply as possible, and presented in a logical sequence. Tables and graphs are often extremely helpful in summarizing large amounts of data. Do not repeat in the text the numerical evidence contained in figures and tables, and do not present the same data in figures *and* tables. Mention any negative results if these are likely to be of interest to other workers in the field. Include unequivocal statements of statistical significance and, if applicable, give some estimate of the accuracy and precision of the results. Avoid vague statements like "there was a general trend to..." or "the tendency was for...".

Do not include results that are not relevant to the arguments being presented.

Discussion

The discussion section is often the hardest part of a paper to write, but it is important to do it well since it is this section that explains the significance of the results obtained. Here you should assess the validity of the results, relate them to previous work, and comment on their significance and theoretical and practical implications.

Try to present the principles, relationships, and generalizations shown by the results. Do not simply repeat what you have already said in the results section.
Do not reconsider every part of the work in minute detail.
Discuss any results that do not fit in with the general pattern. Do not try to hide them or to "fudge" the data.
State your conclusions as clearly as possible, and summarize the evidence for each one.
Point out any results that suggest new lines of study.

Acknowledgements

The acknowledgements section should mention the contributions of people who were involved in the study in some way but who do not qualify for authorship. It may include people who provided technical help, or financial or material support. People who made an intellectual contribution to the study, but whose contribution did not justify authorship, should be named and their contribution described. You should obtain written permission from the individual concerned if you mention anyone by name.

References

Most journals have their own house style for references and you should consult the journal's instructions for authors when drawing up the reference list. However, over 400 medical journals have agreed to receive manuscripts prepared in accordance with the Vancouver guidelines drawn up by the International Committee of Medical Journal Editors, and this is the style that will be discussed here.

You should number references consecutively in the order in which they appear in the text. Identify references in text, tables and legends by Arabic numerals in parentheses. References cited only in tables or legends should be numbered in accordance with a sequence established by the first identification in the text of the particular table or illustration. List only significant published references. Do not include unpublished data or papers in preparation. Check all parts of the reference against the original publication—do not assume that a citation in someone else's paper is correct.

The essential elements of a bibliographic reference are as follows:

For a journal article: authors, name of article, name of journal, year of publication, volume number, page numbers.

For a book: authors, title of book, place of publication, publisher, year of publication.

For examples of reference style, see:
International Committee of Medical Journal Editors. Uniform requirements for manuscripts submitted to medical journals. *British medical journal* 1991; **302**: 338-341.

Tables

Appropriate tables (and illustrations) help to improve the understandability and presentation of a scientific paper. After reading the title and the abstract, many readers often glance through the tables and illustrations before deciding whether or not to read the text. Well presented tables and illustrations can entice readers to take more interest in the paper.

What is a table?

The *Collins English Dictionary* defines a table as "an **arrangement** of words, **numbers**, or signs, usually in **parallel columns**, to display **data** or **relationships**".

Note that data should be arranged in a *logical manner* with a view to presenting specific *inter-relationships*.

How many tables?

A typical scientific paper is about 3300 words long and contains four tables or illustrations. This means that on average there is one table or figure per 1000 words; most journals accept this ratio.

Why some journals restrict tables and illustrations

Typing tables, especially long ones with lots of data, is quite tricky, and requires a special flair; it also takes longer than typing simple text. This also applies when printers compose tables and consequently increases the cost of typesetting. Hence most journals will permit only the most relevant tables.

Parts of a table

Certain terms are used to describe parts of a table. Authors should also know them as editors may refer to them in correspondence about revision of the paper.

Title. The title always begins with the number of the table, and briefly describes the contents of the table.
Field.: The space that carries numerical and other data in which rows (horizontal) and columns (vertical) are arranged.
Column headings. What is included in each column must be clearly stated in the column headings. There must be a good explanation for the way in which columns are arranged from left to right, e.g. the first column may identify patient number and the next series of characteristics in the order in which the measurements were made (temperature, blood pressure, etc.).
Heading straddle-rule. This line helps eliminate any uncertainty about which column headings are included under the grouped-column headings.
Rows. Rows include data with respect to each column heading.
Row headings. These can be created by indenting items under headings, as follows:

Treatment group
Men
Women

Footnotes. Footnotes include supplementary information—details of the contents of the table that cannot be included in the title.

Logical structure of a table

The reader should not have to refer to the text to understand a table. Hence a clear (but brief) title will help. Use the same rules in thinking up a title for a table as you would use in thinking up a title for your paper. For example:

—ensure that the title states exactly what the table contains;
—eliminate unnecessary words;
—avoid repetition of column headings and rows in the title (e.g. instead of "Temperature and blood-pressure measurements of 20 patients following treatment with 200 mg of RU486" you may say "Clinical changes following treatment with 200 mg of RU486").

Arrange columns left to right in a sequence that reflects, for example, the sequence in which data were collected (over time, in the clinical course, etc.).

Arrange rows top to bottom also in a logical order, for example, by age of the patients (youngest being in the first row).

Illustrations

The purpose of an illustration is to *communicate information visually* (as opposed to in the form of prose.) By definition, visual communication is lucid, hence rapid. The keyword is *communication.*

Deciding when to use illustrations

Many of the rules about redundancy of tables apply to illustrations as well. Like tables, illustrations are expensive to produce, not only for the journal but also for the author.

Three key points about illustrations—evidence, efficiency, and emphasis

Evidence. "Seeing is believing". So if you have visual evidence to support your argument, present it as an illustration. Use a photograph or an electron micrograph where visual evidence is vital to the presentation of your findings—e.g. histological changes following treatment with steroids.

Efficiency. When used correctly, illustrations are an efficient way of presenting descriptive data (a new technique of vasectomy or vas occlusion, clinical manifestations, maps showing distribution of a disease, etc.). Numerical data presented in a table can often make the same point, but if you want to show the relation between two variables a graph may illustrate that point more readily and forcefully.

Emphasis. If the purpose is to stress a point—such as higher maternal mortality due to induced abortion in one region of the world compared with another region—then a simple bar graph can do this effectively. But many such illustra-

tions (showing emphasis) are generally more suited to presenting findings in a lecture rather than a scientific article, where for reasons of space such emphasis may sometimes be better expressed as text.

General principles for presenting data in the form of illustrations

Data quality. Smart illustrations will not overcome inadequacies in the quality of data.
Selectivity. Only selected and most relevant data should be displayed in illustrations. An excessive number of tables and figures in an article will render comprehension difficult.
Repetition. Data should be presented in one form only (text, table, or figure).
Uniformity. Similar data should be displayed in similar form.
Focus. Every illustration should make a specific, convincing point.
Simplicity. Illustrations should be kept as simple as possible. Avoid abbreviations, too many words, explanatory details of symbols used, etc. Keep the title simple; follow the same rules as given for titles of tables.
Independence. All illustrations should be readily understandable without the need to refer to the text.

When not to use illustrations

If the same thing can be said simply, briefly, and convincingly in the text, do not use an illustration. Save illustrations for concepts that are difficult to present in the form of prose.

If the same thing has been said in the text or shown in a table, do not use an illustration.

If the three key criteria mentioned above (evidence, efficiency, and emphasis) are not satisfied, do not use that figure.

Selecting appropriate form for displaying data

First decide why data need to be presented in an illustration (the three key criteria). The purpose will dictate the type of illustration that should be used.

If exact values are important, a table is preferable to a graph.
When trends and relationships are more important than exact values, a graph is more forceful and readily comprehensible (provided your data permit this).
When location with regard to data is important, use a map with appropriate shading of areas.
If a series of steps needs to be presented, it may be more efficient to present the information in the form of an algorithm.
If processes or systems need to be described, a flow-chart is usually more efficient than prose.

Preparing illustrations

Get professional help if you can. For certain types of illustration (maps and line drawings) most authors will need the services of a professional artist.

Many microcomputer-based programs are now available for producing graphs (Harvard Graphics, Clickart, Canvas, etc.). It may be worth investing some time in learning some of these programs. Most are not too complicated.

But whichever way you produce your illustrations, attention must be paid to the following two points:

Size. Along with their numbers, many journals restrict the size of illustrations, sometimes to as little as eight centimetres in width (commonly used column width for two-column layout). Note the restrictions carefully, and plan your illustrations so as to utilize the maximum permitted space.

Style. Lines and letters of different weights can be used to improve the overall appeal and legibility of illustrations (see Annex 2).

CHOOSING THE JOURNAL

Even before starting to write the paper, you should have decided on the journal to which you intend to submit the finished report. In making this decision, the following features may be relevant:

—the scope of the journal
—the prestige of the journal
—its circulation
—the frequency of issue.

A number of journals may seem suitable. In deciding among them, think about your paper. What sort of people are going to want to read it? Is it likely to be of interest only to specialists in your field or is it of wider relevance? Check the journal's statements of scope and purpose to make sure that the topic of your paper will be acceptable. Look critically at examples of the different journals. Examine the scientific quality of the articles published. See how well the illustrations are reproduced. Try to find out which journals have a reputation for fair editorial review and helpful refereeing. Try to find out the average delay between submission of manuscript and publication.

TYPING THE MANUSCRIPT

Type the manuscript in double spacing, including title page, abstract, acknowledgements and references. Each manuscript component should begin on a new page in the following sequence: title page, abstract and key words, text, acknowledgements, references, tables (each one on a separate page), and figure legends. Illustrations should be unmounted glossy prints or original line drawings.

SUBMITTING THE MANUSCRIPT

Once you have decided on a journal, obtain and read its Instructions to Authors, and follow them when preparing your manuscript. As noted earlier, many medical journals will consider papers prepared in accordance with the Vancouver guidelines, and this will normally be stated in the Instructions.

You should *not* submit your manuscript to more than one journal at a time. Submit the required number of copies in a heavy paper envelope. Enclose a covering letter signed by all the co-authors and containing:

—information on prior or duplicate publication or submission elsewhere of any part of the work;
—a statement that the manuscript has been read and approved by all the authors;
—the name, address and telephone number of the author to whom correspondence should be sent.

You should also include copies of any permissions to reproduce already published work. Most journals will require you to assign copyright to them. Keep a copy of everything you send.

RESPONDING TO EDITORS

You should expect to receive an acknowledgement of receipt of your manuscript within 2–3 weeks and a decision regarding publication within 6–8 weeks. If you have not received a reply within 8 weeks, you are justified in contacting the editor of the journal to find out what is happening. The most likely explanation is that the editor is waiting for comments from one or more reviewers, but it is possible that your manuscript is lost, and a polite inquiry can save weeks of uncertainty.

Bear in mind that most journals receive many more papers than they can possibly publish, and that the rejection rates of the best journals are often over 50%. A number of criteria are likely to be applied by the editor in making his or her decision:

—relevance of the paper to the journal's scope and audience;
—importance of the paper's message to most of the journal's audience;
—newness of the paper's message;
—scientific validity of the evidence supporting the paper's conclusions;
—other similar papers recently published or accepted;
—effect of acceptance on the journal's backlog of accepted papers;
—quality of presentation in the manuscript.

The decision will then be either to accept the paper as submitted, to reject it, or to request modification of the content or structure. Outright acceptance is very rare—probably only 5% or so of papers are accepted without change. It is more likely that acceptance will be provisional, pending a number of modifications. These modifications may be technical, e.g. including more details of a study

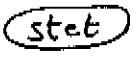
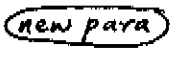
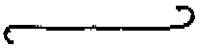
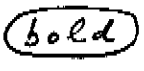
group or method, or presentational, e.g. shortening the text or reducing the number of illustrations. You should then revise the paper along the lines suggested and resubmit it, with a covering letter detailing the changes made. If you feel that you cannot accept some of the suggestions, you should also mention these in the letter, and explain why you have not made the changes. Do not simply ignore the suggestions you do not agree with. If you do, the manuscript is likely to be returned once again with a request for further changes.

If you receive a rejection letter, usually the editor will include the comments of the reviewers, which are likely to give some indication as to why the paper has been deemed unacceptable. A good reviewer will try to make his or her comments constructive, rather than destructive, and will often suggest ways in which the paper could be improved or, if necessary, further experiments or analysis. You should examine the reviewers' comments carefully and, as far as possible, objectively. If they suggest that parts of the paper should be revised, it is a good idea to do so before submitting it for publication elsewhere. It is not usually worth challenging the editor's decision unless you are absolutely sure that the reviewers have seriously misunderstood your manuscript. Even then, you should consider the possibility that their misunderstanding may be due to the way you have presented the report.

READING PROOFS

Once your paper has been accepted for publication, it will usually be copy-edited to correct spelling and grammatical errors, and to put the paper in the style of the journal. The paper is then keyboarded for typesetting, and you will usually be sent a galley proof for checking. Note the word *checking*. This is not the time to start rewriting your paper, or adding bits of information that you

Table 1. Common proof-correction marks

Instruction	*Mark in text*	*Mark in margin*
Insert		letter/words to be added
Delete	/ or ⊢⊣ through characters to be replaced	
Stet (undo change)	dotted line under words to be left unchanged - - - - - -	
Substitute new material	/ or ⊢⊣ through characters to be replaced	new material
Capitals	treble underlining 	
Lower case	circle letters to be changed	
New paragraph		
No new paragraph (run on)		
Print in italic	underline words to be italicized	
Print in bold type	wavy line under words to be in bold	

think would be interesting to the reader. Proof correction is expensive, and the editor is likely to ignore any changes that are not necessary.

You should read the proof twice—once for spelling and typographical mistakes and once for sense. Check especially all numbers and all technical terms. It is also a good idea to ask someone else to read your proof—the author is often so familiar with the material that he or she sees what should be there rather than what is there. The copy-editor may also have marked a number of queries on the proof; you should answer all of them.

Mark all corrections in the margins of the proof, with corresponding marks in the text itself. The mark in the margin tells the compositor what the change is—a letter missing or a word to be deleted, etc. The mark in the text shows where the change should be made. Table 1 shows a few of the more common proof-correction marks.

SUMMARY OF STEPS IN WRITING A PAPER

The list below outlines the steps required in preparing a paper for publication. It is not intended to be followed slavishly; each writer will have his or her own way of working and will need to adapt the list accordingly. It does however provide a useful framework and checklist.

1. Decide on the message of the paper and the target audience; select the journal to which you will submit the finished paper.
2. Obtain and read the Instructions to Authors of the journal chosen.
3. Decide on the authors.
4. Draft a working title.
5. Develop an outline for the first draft.
6. Design tables and illustrations.
7. Write for permission to reproduce any previously published material.
8. Put the manuscript away for a few days.
9. Re-examine paper and revise structure.
10. Write the first draft.
11. Check illustrations and tables and make final versions.
12. Check all references for completeness, consistency and accuracy.
13. Correct the grammar and polish the style.
14. Ask for criticism from co-authors and friends.
15. Write a revised draft.
    Repeat steps 14 and 15 as many times as necessary.
16. Compose a final title and write the abstract.
17. Compile the final reference list.
18. Obtain a critical review of the final paper from a senior colleague.
19. Make any corrections necessary.
20. Write a covering letter to the editor of the journal, enclosing copies of letters giving you permission to reproduce published material.
21. Put together all parts of the paper, including illustrations, and post as many copies as required to the editor.
22. Respond to the editor's decision; revise as requested; resubmit the revised paper or submit it elsewhere.
23. Correct the proofs.

Annex 1

Revising prose style

Editors do not expect people brought up speaking other languages to be able to write perfect English, and you can expect the copy-editor to correct the obvious errors. However, you should make an effort to express yourself as clearly as possible and to avoid major grammatical mistakes, particularly those that could lead to ambiguity.

The key for all scientific writing, but especially for authors whose mother-tongue is not English, is "keep it simple". George Orwell, a well known English novelist, summed up the rules for writing good English as follows:
1. Never use a metaphor, simile, or other figure of speech which you are used to seeing in print.
2. Never use a long word when a short one will do.
3. If it is possible to cut out a word, always cut it out.
4. Never use the passive when you can use the active.
5. Never use a foreign phrase, a scientific word, or a jargon word if you can think of an everyday equivalent.
6. Break any of these rules sooner than say anything outright barbarous.

Metaphors, similes and figures of speech

As a general rule, metaphors and similes have no place in scientific papers. If you feel that you must use them, be very, careful. Some of the possible pitfalls are illustrated in the following sentences:

—Scientists at Caltech have announced the discovery of a virgin field pregnant with possibilities.
—We congratulate the Chairman on his skill in piloting the Committee's ship on to the solid ground of reality.
—The strong arm of the law is marching after the offenders.

Long words and short words

Many writers use long words in the belief that it makes them appear more learned. It doesn't. It simply makes life harder for the reader, and increases the risk that a word will be used wrongly. So, do not use a long word when a short one will do. Prefer:

use	to	utilize
give	to	donate
cause	to	be conducive to
if	to	in the event of
best	to	optimum
send	to	transmit.

Cutting out words

Go through your text and examine each word and phrase to see whether it is really necessary.
Cut out all long-winded introductory phrases such as "It is of interest to note that..." and "Careful examination of Table 2 will demonstrate that...". Remove unnecessary adjectives and adverbs, with special attention to vague qualifiers, such as quite, very, fairly, rather, relatively. Watch out for tautologies—do not reach a final conclusion on the necessary prerequisites for an absolutely unique approach to a puzzling enigma.

Another common problem is the use of abstract nouns instead of verbs. Thus, many authors do not investigate, they carry out an investigation; they do not consider, they give consideration to. Watch out in particular for words ending in "-tion" and for weak verbs like achieve, effect, produce and bring about.

Passive v. active

The active voice is usually more precise and less wordy than the passive. This is not to say that you should never use the passive; it is often appropriate in scientific writing. But it should not be overused. So, for instance, avoid phrases like "the placenta is crossed by melatonin"; write instead "melatonin crosses the placenta". The passive voice has traditionally been used in scientific writing to refer to the thoughts or actions of the author: thus, "it is thought that..." rather than "I think...", and "it has been found that...", rather than "we found...". This tendency is slowly changing, and many journals now encourage authors to use the first person in their writing.

Annex 2

Line and Letter Weights in Graphs

Weight	Type of line or letter				
	Line graph[a]	Bar graph, Component bar graph	Individual value bar graph	Histogram, Frequency polygon	Pie graph
Boldest	Curves	Outline of bars	Lines showing means or connecting data points	Outline of graph	Outline of graph
Less bold	Axis labels				
	Outlines of white data points Confidence limits	Axis and class labels	Axis labels	Axis labels	Segment lines Segment labels
Least bold	Axes Tick marks Scale numbers Curve labels Keys Statistical error bars	Axis Tick marks Scale numbers Keys Segment labels[b] Statistical error bars	Axes Tick marks Scale numbers Baseline (if drawn) Statistical error bars	Axes Tick marks Scale numbers	Leader lines

[a] For insets in line graphs, line weights are the same as for the main graph, except that curves are less bold and letters and numbers are smaller. Data points are also smaller.

[b] In composite figures, the letters or words that identify each part of the composite should be the boldest letters on the graph.

[c] For component bar graphs.

Source:
SCIENTIFIC ILLUSTRATION COMMITTEE OF THE COUNCIL OF BIOLOGY EDITORS. *Illustrating science: standards for publication*. Bethesda, MD, Council of Biology Editors, 1982.