Tips on Writing Papers

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Every scientist wants his or her paper to be read, yet many scientific papers are readable only by specialists in a narrow area. Even papers in specialty journals should be written so non-specialists can understand something about the concepts and results. The tips presented here are based on observations of how readers select papers to read and how they decide whether or not to continue reading.

Title − A scientist interested in your topic will likely find your paper through a key word search. Sifting through the many titles that come up in a search, a prospective reader will decide from your paper's title whether to take the next step and read the abstract. Hence it is important to think carefully about the choice of words in the title. Make a list of words that describe your work, and use that list to form a short title, at most ten words long. Avoid jargon, clever double meanings, and empty words and phrases such as "new, novel, study of, investigation of, exploration of, precision, high resolution, efficient, powerful."

Abstract − An abstract should address the obvious questions: What have you done? How did you do it? What is new here? Why is interesting? What are the ramifications?

Write for as broad an audience as possible, but also be succinct and quantitative, as in

> "We find that the scaling of the susceptibility X with temperature difference ΔT is given by $X \propto (\Delta T)^{\alpha}$ with $\alpha = 0.52 \pm 0.03$ rather than the predicted value $\alpha = 5/4$."

A carefully written abstract is crucial because most readers will skip on to the next paper after reading a sentence or two of an abstract. Further, only a small fraction of those who read the whole abstract will go on to read the paper online or download and read a pdf.

Introduction − Almost no one reads a paper continuously through the successive sections – Introduction, Background, Methods, Results, Discussion, Conclusions. Many persons read a paragraph or two of the Introduction and then jump to the Conclusions. Others look first at the figures before reading any of the text. A reader who encounters many unfamiliar terms is likely to give up and move on to peruse another paper. If the work involves many different quantities or variables, a table with definitions and/or relationships will be helpful to readers.

The Introduction should describe the issues and open questions that motivate your work. How does your work fit in? How does your work differ from previous related work?

Background − If the topic has an extensive history, the literature review can be part of a separate "Background" section, but if there is scant relevant previous research, the literature review can be included in the Introduction. Conduct a thorough literature search using *Google Scholar*, *ISI Web of Science*, and *www.arxiv.org*. Search using key words and names of authors of key papers. Also use search engines to find recent papers that have cited the key papers on your topic.

References − Referencing relevant prior work is not optional. Follow the American Physical Society Guideline on References in Publications:

> *Proper and complete referencing is an essential part of any physics research publication. Deliberate omission of a pertinent author or reference is unethical and unacceptable.*
>
> See https://www.aps.org/policy/statements/02_2.cfm - supplementary_guidelines3

Figures − After deciding on your main point and writing an abstract, create a set of figures or sketches for figures. Clear simple figures communicate more effectively than text because our brains process images much faster than words. Readers are more likely to remember a figure than text. Years later you will not regret having spent days preparing a single figure that other authors later include in their papers and textbooks.

Each figure with its caption should tell a self-contained story. Begin the caption with a short phrase or sentence stating the point illustrated by the figure, and follow with the details. The caption "The function *f(x)* is plotted as a function of *x*" is of no help.

A recommended resource on preparing figures is E.R. Tufte's *The Visual Display of Quantitative Information*. Tufte emphasizes that one should maximize the ratio of ink representing data to ink used for everything else, including axes, labels, and arrows.

Methods − A shocking number of papers lack information essential for replication of the research. This omission is unscientific and is an indication of sloppy work that will have no lasting value.

Experiments − Describe the sample preparation method, measurement and computational procedures, and data analysis. Give all parameter values; do not forget those parameters that are not varied. Use consistent units; SI units are usually preferred. State the uncertainties in the measurements and describe how the uncertainties were determined.

Numerical simulations − State the boundary conditions and initial conditions, and give the size of the temporal and spatial meshes; test the convergence of your results as a function of mesh size, and describe the convergence test.

Theoretical analyses − State the assumptions, approximations, and normalizations, and be clear about changes of variables.

Results − Many readers start by reading the Results or Conclusions, so do not assume that readers know the definitions and other information given earlier in your paper. Present only material essential for your story. Most research includes steps that turn out to be irrelevant to the final result. A blind alley may have taken many months, so there is a temptation to describe such missteps, but don't unless your misstep is one that others are likely to make.

The Results should unfold in a logical way. Re-read your Results section multiple times, culling paragraphs and figures that are not needed for the main message. Avoid the temptation to describe the story in chronological order; your own random walk toward the solution of a puzzle will confuse rather than inform readers.

Include only essential figures. Readers become overwhelmed and confused by a large number of figures, and figures with many curves or many panels.

Discussion − Describe how your results solve a long-standing puzzle or extend prior work. Do not include additional results in the Discussion.

Conclusions − After the Introduction, the Conclusions section is probably the most read. Some readers even jump from the Abstract to the Conclusions. Thus do not assume that readers know definitions given in the body of your text. Summarize your key results without repeating phrases or sentences that have appeared in the abstract or previous text. Mention key figures. Put the results in the context of past work, and point to new questions that your work raises.

General Comments

Section Headings − Make generous use of brief headings and subheadings to guide the reader.

Paragraphs − Introduce the main idea of a paragraph in the first sentence, and follow that with clear and simple supporting sentences that focus on the main idea. Avoid digressions from the paragraph's focus. Break long paragraphs into several paragraphs. The closing sentence should reinforce the point of a paragraph.

Linkages − Facilitate the readability of your paper with sentences that link one paragraph to the next and one section to the next. These linkages make it easier for a reader to understand where you have been and where you are going.

Word choice − Write for the broadest possible audience. Avoid jargon, acronyms, and superlatives, and avoid extraneous phrases such as "it is a fact that…" or "it is well known that". Understatement is preferable to hyperbole; avoid "unique, ultra, very, novel, innovative, perfect, super, remarkable, extraordinary."

Avoid repetition − Repetition is tiresome. Avoid repeating phrases, sentences, and concepts. Do not repeat or say again what has been said before. Do not include the same information in the text and in a figure caption. Repetition is tiresome.

Grammar − Use a standard writing style guide such as Strunk and White's *The Elements of Style* or *The Chicago Manual of Style*; both are available as free pdf downloads.

Most important tip: re-write, re-write, re-write. Become your own severest critic. Read the text out loud either alone or with another person to check the flow of sentences and to find ambiguous or irrelevant statements. Ask colleagues and friends to critique your manuscript, and volunteer to critique theirs. The most helpful critics are often those unfamiliar with the subject matter.

Writers tend to become attached to their text and reluctant to make revisions. Listen carefully to the questions your readers raise, and respond by revising your manuscript rather than becoming defensive. Cut material not essential for your story. The longer a paper, the fewer readers it will have. Delete words, phrases, sentences, paragraphs, figures, tables, and sections that are not necessary. Lengthy details can go into an appendix or supplementary information.

Finally, give the preparation of a manuscript an effort comparable to that put into the experiment, computations, and analysis. Developing clear arguments is an essential part of the creative process and often leads to new insights. A well written paper will garner the attention that the research deserves, while an ingenious result presented poorly may go unnoticed.

Work sheet for writing a title and an abstract

List key words that describe your work: _____

_____

_____

_____

Draft five different titles:

- *Remember:* you want researchers who find your title in a key word search to take the next step and ***read your abstract***.
- Try for fewer than ten words in each title.
- Avoid jargon and acronyms.

1) _____

2) _____

3) _____

4) _____

5) _____

Writing the abstract

- length: ~4 sentences (< 600 characters) in *Physical Review Letters*
  ~8 sentences in *The Physical Review*, *Science*, *PNAS*, or *Nature*
- incorporate your key words

To prepare your abstract, first write brief answers to the following questions, which should be addressed in the abstract.

What is the problem? _____

_____

_____

Why is it interesting? _____

_____

_____

How have you addressed the problem? _____

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What are your results? _____

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How do your results impact both past and future research? _____

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