Tips on Scientific Writing

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1 Elements and structure.

Everything you write—papers, letters, your thesis, books, reports, proposals, etc.—should contain at least the following elements:[1]

- **Introduction**
- **Body**
- **Conclusion**

Scientific papers also contain **references**, **figures and/or tables**, **acknowledgements** and, sometimes, **appendices**.

Introduction. Here you provide the **context** for your paper. Your introduction is your only chance to catch your reader's attention. *Here you must make your topic sound so interesting that your reader will want to learn about it.* You must also describe clearly and succinctly the topic of your paper. This description must be specific and focused, not vague and all-encompassing. It must give your reader a clear idea of *precisely* what your paper is about. Finally, your introduction must focus your reader's attention *inward* towards the detailed discussion that will comprise the Body of your document.[2]

Body. Here you develop a *logical sequence* of ideas that will lead your reader to an understanding of the points you're trying to make.[3] Depending on the topic of, constraints on, and venue for your paper, the Body might contain historical background, details about experimental apparatus and measurements, relevant physical concepts, necessary mathematics and derivations (as few as possible), figures, tables, and so forth. *The Body of your paper must be organized logically, not chronologically. Your paper is not a diary. Its job it to explain your findings, not narrate the sequence of events that led you to them.*

Conclusion. Here you move your reader's focus *outward* from the detailed discussion in the Body of your paper. Here you also bring the paper to closure. *One of the worst mistakes a writer can make is to end a paper without a conclusion.* What you write in your conclusion is what your readers will remember. If you just stop, your readers will remember nothing.

[1] Almost all scientific papers have a section called **Introduction** and a section called **Conclusion**. Do not, however, title the Body of your paper **Body**. (I have actually seen this offense in a paper submitted to a professional journal.) Instead, devise a *short*, succinct title for this section that describes what it is about (e.g., "The Theory of the Photon" or "The Physics of Bose-Einstein Condensation" or "The Compton Experiment"). Devise *short*, specific, meaningful titles for all subsections. Your titles should enable your reader to see *at a glance* the topic of each section and subsection.

[2] *Never* write tacky sentences that begin with phrases like "My topic is..." or "This paper is about ...."

[3] Give each idea *at least* one paragraph. Each paragraph should make and discuss one (and only one) point. One sentence in the paragraph should indicate clearly what the paragraph is about. As you revise your paper, check each paragraph for this information. If you can't find it, you must revise the paragraph or combine it with a prior or subsequent one.

Appendices (optional). Appendices contain information that doesn't belong in the Body of your paper. For instance, appendices are good places for mathematical derivations, apparatus details, or additional tabulated data.

References. Your reference list serves three purposes. First, your reference list gives credit where credit is due. *You must provide a reference for every insight, paraphrase, result, derivation, idea, or direct quotation you take from another source. Failure to properly cite the literature you used constitutes* ***plagiarism****, one of the most heinous crimes in science.* Second, your reference list provides your reader with *carefully selected* background references. Doing so is important, because one of your jobs is to enable your reader to gain the background required to understand your work. Third, your reference list contributes to the **context** of your paper, situating it in the field in which you're working.

Figures. Whenever possible, use figures—rather than tables—to illustrate, clarify, and emphasize the points you want to get across. But use figures selectively. Don't show absolutely every result you generated. Some results (especially from tests you've done) can be summarized in the test. When preparing figures for your paper, follow these four rules. First, each figure caption must identify unambiguously each element (points, lines, etc.) in the figure. The caption must also explain *briefly* the content of the figure, so a reader can understand the essence of the figure from the caption alone. Second, each figure must be cited *and discussed* in the Body of your paper. *Never include a figure without explicitly discussing it.* Third, axes on each figure must be labelled, including units wherever required. Fourth, make your figures consistent. That is, in all figures that show data of the same type, use the same line types and symbols.

Tables. Tables in a scientific paper serve two purposes. The primary purpose of a table is archival. *As a permanent record of the hard work you've done, figures are not sufficient!* You must include tables of selected or complete results for any data you want anyone to use in the future. (Many journals have on-line resources where they will make available data you provide. Use these resources when you have so much data that it makes no sense to try to include it all in your paper. If you're in this situation, though, you should consider including a table of *selected* results in the paper.) The secondary purpose of tables in a scientific paper is to make a point you can't make in a figure.[4] *Except to accomplish these two purposes, avoid tables.* Tables are almost always much less effective than figures. Figures are much easier for readers to assimilate and authors to discuss. A few pointers: Every table must have a caption. All tables must be cited and discussed in your paper. *Never include a table without explicitly discussing it.* Take extra care when you write the caption to a table. Future students and scientists *will* use data you tabulate. If you are not very careful *and explicit* in describing the precise content of a table, they will (unintentionally) misunderstand and misuse your results. *Always include units (as appropriate) for every column (or row) of your table.*

2 Principles.

1. **Don't "write." Rewrite.**

   There is no "final draft" of a paper. Plan from the outset to revise your paper many times. Keep revising until you run out of time or get so sick of your paper that you just quit.

[4] For example, sometimes you need to show a more precise comparison of data sets than you can accomplish with a figure.

2. **Do one thing at a time.**

   Writing a paper (a letter, a proposal, a quiz, instructions, etc.) requires lots of steps. You need to organize your ideas; figure out how to explain your ideas; decide how to illustrate your ideas; choose the equations, figures, and tables you'll include; decide how you're going to say what you're going to say; devise effective transitions between items you're discussing; check spelling; fix grammar; polish your prose; include references; and *lots* more. The longer the document, the more steps you must complete. It should come as no surprise that to try to do all these things at the same time is to invite confusion, stress, and disaster.

   Do first things first. Brainstorm your ideas. Then organize them into a logical sequence. Then write about your ideas in general terms, not worrying about technicalities. then look at what you've written to see if your ideas follow one another logically. If they don't, rearrange them and try again. Then decide what figures, tables, equations, etc. you must include to explain your ideas. Then write a draft. Revise it a couple of times. And again. And so forth.[5] If possible, get input from other readers. Revise again.

3. **Develop your paper from the inside out.**

   Write the Body first. You can't write the Conclusion before you write the Body. And it's *much* easier to write the Introduction once you know what you're introducing. Write the abstract and title last.[6]

4. **Don't try to write "polished" early drafts.**

   Every draft should be readable and free of grammatical errors. But don't waste time trying to perfect early drafts. The purpose of an early draft is to get your ideas on paper in some sensible sequence. Polish during late revisions.[7]

3 Strategies and Tactics.

There is no trick to writing an effective paper. *The more you revise your paper, the more effective your paper will be.* At some step in the development of your paper, you need constructive feedback from someone else. Choose your reader carefully. Your reader should be someone in the audience you've defined for the paper, someone who can be objective and constructive, and someone whose judgement you trust. Don't give your reader an early draft of your paper! Your reader's time is valuable. Give your reader a draft only when you're reasonably satisfied that your paper does what you think it does. The goal of getting feedback is to find out whether your paper *actually* does what you think it does.

[5] A great way to self-critique a first version is to do something else for a day or so, then come back to your paper and, as objectively as possible, ask yourself the following questions: If I knew nothing about this subject, what in this paper would confuse me? How can I restructure, add or subtract material, or rewrite certain paragraphs to make my paper more interesting and/or comprehensible?

[6] The same principle is useful in writing each element of the paper. For instance, I often write down equations for a discussion long before I actually draft the discussion. Then I can decide exactly which equations to leave in, what notation to use, and what I need to tell my reader *before* I have to worry about the prose I need to stitch the equations together and how I'm going to get the reader into and out of the derivation. Do the same thing with figures, tables, the introduction and conclusion, and other elements of your paper.

[7] As you revise, you'll probably decide to throw out or reorganize material you've written for early drafts. If you spent time polishing that early material, then you've wasted that time.

- **Write in your own voice.**

  Your prose should be invisible. Its only job is to communicate to your reader clearly and interestingly. Don't use fancy words. Use as little specialized technical jargon as possible. Don't be cute. Don't use colloquial expressions or slang. Strike a balance between conversational informality and arch formality. Use active voice except when you really mean to imply passivity. That is, avoid the stilted, dull "passive voice" construction often found in (bad) science papers. If you're the sole author, use "I" when discussing *your* ideas and conclusions.

- **Always keep your audience in mind.**

  Remember, your reader knows (much) less about your topic than you do.

- **Define all symbols, specialized terms, and abbreviations.**

  Never use a symbol or acronym that you have not defined. Don't use specialized jargon that you have not defined. Use as *few* acronyms as possible. Rule of thumb: introduce an acronym only for a *long* phrase that you're going to use *many times* throughout the paper. For each acronym you do use, give its full name the first time (and only the first time) you use it.

- **Don't pad your paper.**

  Include what you need to make your points. Cut everything else.

- **Discuss each table, figure, or equation you present.**

  Never include a table, figure, or equation that isn't clearly and explicitly related to the points you're trying to make. What's "obvious" to you will almost certainly not be evident to your reader. For each such figure or table, always *explicitly* state what you want your reader to notice or conclude from the item. If you can't do this, cut the table or figure.

- **Don't lose focus. Be selective.**

  Know *in advance* what points you want to make. As you draft your paper, construct a line of argument that aims straight towards those points. *You must justify, back up, and support every point you make.* Don't wander from the main line of argument. No tangents. No detours. Everything ion your paper should contribute to making, supporting, or providing a context for your points.

- **Be specific.**

  Never generalize. As you revise, scrutinize every paragraph and cut all generalizations and vague statements.

- **Tell a story.**

  The best papers have an internal logic that makes readers want to read them. Even when writing a research paper or a technical report, you can (almost always) organize your material so your paper has a well-defined beginning, middle, and end. Construct the Body in such a way that every step follows *logically* from the one before it. *Never* organize your paper chronologically.[8]

[8] First I did this. Then I did that. Then I did this other thing. It didn't work. So I next did this. Yuk.

4 Format.

- **Your paper must be completely free of typographical, mathematical, and grammatical errors.**

  Professionals do not submit error-ridden documents. You can almost guarantee that your paper will antagonize readers, reviewers, and editors by leaving technical errors in it. *Eliminating technical errors from a paper requires time, effort, patience, and persistence. It is hard work that you must do.* Run each draft through a spell checker. Check your figures. Check your tables. Check your references. Get a friend or two to proof it for you. Do whatever is necessary. But *never submit a sloppy, error-ridden paper.* You've invested precious time and energy in your work; your work deserves the best presentation you can give it.[9]

- **Be sure your paper adheres to the formatting requirements of the journal to which you're submitting it.**

  You can find this information online. If you ignore it, then you'll look like an idiot to the editor, and the journal's processing of your paper will be delayed. Neither outcome is desirable.

- **Checklist of things to avoid.**

  Here's a short list of things that turn reviewers, editors, and readers off: typographical errors; gross grammatical errors; the words "obviously," "clearly," "easily,"; padding; jargon; lots of acronyms; undefined acronyms; inconsistent notation; undefined notation; inconsistent jargon or acronyms; missing units; huge paragraphs; paragraphs that make no point; run-on or very complicated sentences; pointlessly intricate mathematical notation, unnecessary derivations; figures that contain so many curves or symbols that readers can't tell one data set from the other; figures that contain curves or symbols that aren't identified on the figure or in the caption; captions to figures or tables that don't explain the content; tiny figures of data you should have tabulated; papers that bury the points they're trying to make.[10]

[9] Have you ever watched a really good movie or TV show on a television whose reception was so poor that there was a lot of "snow" or noise on the screen and lots of static on top of the audio? Pretty irritating, isn't it? That's what reading a good paper which is full of typos is like. Technical errors distract your reader from what you want him or her to focus on—your ideas—to mentally correcting your errors and (with increasing frustration) trying to figure out what you're trying to say. Every error undermines all the hard work you put into researching and writing the paper. Get them all out!

[10] You're writing a paper, not a mystery novel or a joke book. Don't make the reader wait for (or, worse, search for) the punch line to your paper. State your most important points clearly and succinctly in three places: the abstract, the Introduction, and the Conclusion.

