How to write Reports, Theses, and Papers

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The central idea of scientific texts is to *provide reliable information, which the reader can use for further work*. They play a central part of the scientific world, where we all rely on results of others, while we try our best, to reveal new facts and connections. In order to serve this purpose, scientific writing generally follows common standards, which are outlined below. The idea of all of these is to gain the interest of the reader, to ease the understanding and to make it possible to retrieve errors.

1 Structure

Every work has typically the following structure, which is guided by the idea, that the reader shall receive answers to specific questions in each part.

Title with authors and date, to identify the document

Abstract [Content of the work] Which problem/field is treated? Which methods are used? What are the main results of the work? Why is the work of interest? The abstract has to be considered as a text on its own, as it appears in databases. Therefore, acronyms and references should be avoided here. Otherwise they have to be defined both in the abstract AND in the following text.

Introduction [Motivation of the work] Which question is addressed and from which scientific context does it arise? (provide key references for the field such as first articles as well as helpful reviews) Why is the work of particular interest? Which methods are going to be used and why have they been chosen? It is sometimes helpful to refer to the key findings and/or describe the organization of the work.

Body of article [Description of the work and the results] Which *methods* (including assumptions, postulates, or previous data) are applied? What are the *results* and how are they obtained? Which consequences follow from these results? (*discussion*)
For original work (the first time a result is published) it is essential to give sufficient information (detailed account of all relevant parameters and equipment used) so that the reader can in principle repeat the measurement/calculations.

Conclusion [Repetition of the main points] Which key issues should be memorized by the reader? One can add a discussion of remaining open problems.

In minor project reports, which do not present original work, the abstract and conclusion are usually omitted.

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2 General rules for comprehensibility

Reading other peoples work is never easy, as misunderstandings are difficult to repair. Thus one has to be very careful in preparing the work, so that the message is conveyed as smoothly as possibly. The main rules are:[2]

- Establish a *transparent structure* of the manuscript! This is of outmost importance for the comprehensibility. When you start writing, you have typically bits and pieces of different information or results obtained at different times and from different sources. Lean back and try to find logical connections and a thread through the material. Consider to skip parts which remain outside the main thread, even if you spent significant time on them.
- Explain as *clearly* as possible what you are going to say! Avoid uncommon words and abbreviations. Beware of 'lab jargon', i.e. terms which have developed within your working environment, but are rather incomprehensible to others.
- The work shall have an *appropriate length.* Focus on the main issues, otherwise the reader drifts away!
- It is good to have some *motivating admixtures* (e.g., historical aspects, cartoons, loose connections to hot topics), but they must not disturb the logical structure.

3 References

References are probably the most important part of scientific writing as they connect the text with the existing body of knowledge in the field. They can serve different purposes and in any text you write you must provide references to

- All work that is necessary to understand the methods used in the ongoing work (*Understanding*).
- All articles which considered the problem the first time (*Priority*).
- Articles considering similar questions, which help the reader to learn more (*Context*).

References are not required to issues considered as general knowledge (which depends on the level of the work and the kind of publication). A rough definition is the knowledge a student is expected to have before starting to work on the topic. Thus do not give reference for Schrödinger's equation unless you use an uncommon formulation. In order to enable the reader to find the work, you refer to, you *must follow standard procedures for references.* It is most common to have a list of references at the end of the work and cite these references at appropriate places in the text.[3] In order to identify the individual references there are two main schemes. In the Harvard style, the list of references is ordered alphabetically and one cites a source by the surnames of the authors and the year of publication [e.g., Miller (1999)]. In the Vancouver style, the list of references is numbered and one cites a source by providing the corresponding number either in brackets [9] or as a superscript[9].

Each item in the list of references *must contain the following information*, which enables the retrieval of the work:

Journal article: Authors (all surnames with initials, for plenty of authors you may restrict to the first author and add *et al.*), Name of journal, Volume (often in bold face), first page

[2]These are the four main points of the *Hamburger Verständlichkeitskonzept*, see I. Langer, F. Schulz von Thun, R. Tausch *Sich verständlich ausdrücken* (Reinhardt, München 2011), in German

[3]Note that this does not hold for the abstract, which is a text on its own. If a reference is absolutely required, the bibliographic information has to be added in the text. E.g. 'We show that the findings of Stupid *et al.* [J. Fantastical Physics **23**, 99 (1995)] are not valid because...'

of article (or article number), and year of publication. Optionally, one may insert the title for the work (after the authors, often in italics), the issue of the journal or further information of relevance.

Book: Authors (all surnames with initials), *Title of book* (often in italics), publisher, location of publisher (a town), and year of publication. If relevant, one adds the number of the edition (e.g. 3rd edition).

Thesis: Author (surname with initials), *Title of Thesis* (often in italics), Type of thesis (e.g. Masters-thesis), name of university, and year of publication.

Article as part of book: Authors (all surnames with initials) 'in', *Title of book* (often in italics), 'edited by', Name of editors (all surnames with initials), publisher, location of publisher (a town), and year of publication. Optionally, one may insert the title of the article, the starting page or similar relevant information.

If Harvard style is used, the year of publication follows directly the authors names. Using bibtex of the text processing tool LaTex is a convenient way to organize references and print them according to the different styles of different journals. Finally note, that all items in the list of references should be referred to in the text.

4 Figures

Figures serve usually for two different purposes: The visualization of issues discussed in the text (sketches, flowcharts, picture of apparatus, etc.) and the presentation of data obtained from numerical calculations or measurements. Next to these technical issues, figures are very important for the general appearance of a work, as they catch the eye. Most readers have a look at the figures before they read the text (if they read it at all). Therefore, the quality and proper selection of figures are of highest relevance for the assessment of the work.

Each figure must have a self-explanatory caption, so that the reader can get an idea about it without reading the text. You should include information about the method (such as "density matrix calculation", "STM image", or "under pulsed operation", etc) by which the data is obtained. This is indispensable if different methods are used in the work. *If the figure is taken from somewhere else, this has to be clearly mentioned in the caption together with a proper reference for the source!* Be careful with copyright issues!

For the technical quality of figures the following points are important:

- All axis must be labeled, where the units are in round brackets. Example: "Current (A)"
- If you show different data in one figure (typically with different linestyles or symbols), you must clearly state, what is shown by each line. This can be done via a legend or an explanation in the caption. Often, a combination is useful such as writing in the caption "The full lines provide the current as a function of bias for different lattice temperatures" and have the legend blue line "200 K", red line "300 K". But avoid to repeat the legend in the caption.
- All characters must be easily readable in the final size. It is good practice if axis labels have the same size like the characters in the caption.
- If you use colors, try to make the figures also legible in gray-scale (e.g., choice of colors, line-style, marking of individual curves, indicating the trend of parameters). This is both of relevance for people with color blindness and the possible publication in journals, where high extra fees are required for color figures
- Avoid exponential notation (in particular not of the sort 4.5e5 as some drawing programs do). Use units with prefixes (such as 'I (pA)') or , if unavoidable, '$I\,(10^{-7}$ A)'.

5 Originality

Any scientific text is assumed to document *the author's* understanding of the topic. Simultaneously, every work is based on previous work by other people as documented by different kind of literature (books, articles, notes, web pages, ...). Here particular care has to be taken in handling these sources, as the work will be considered as plagiarism otherwise[4]. Next to the general rules for references and figures given above, this implies:

- The text is written by the author and any help by others in preparing the work is explicitly mentioned (e.g. in the acknowledgment).
- If one provides a line of arguments following closely another text, this has to be clearly stated (e.g. with text like 'This section follows essentially chapter 5 of Ref. [2].' at the beginning)
- If any piece of text is directly copied (even with minor adaptions) from a different source, this has to be clearly marked (e.g. by quotation marks together with the reference), so that the reader directly can identify such parts.

Violation of these rules can lead to severe consequences including a later withdrawal of the academic degree.

In a project report or a masters thesis it is expected that the student includes *all* sources he/she worked with during the preparation in the list of references. In a PhD thesis or a journal article the author has typically read plenty of books and articles, so that he/she restricts to those which turned out to be relevant.

Should you have problems with English language or a disability affecting your writing, contact your supervisor. Never try to cover it by copying text. **There is no excuse for plagiarism!**

6 How to gain the interest of the reader

Your article/thesis is of zero value if nobody reads it. Thus it is crucial that you draw the attention towards your work for potential readers. As most readers have limited time and are not willing to take a closer look at potentially boring stuff, this process must take place during the very first encounter with your text. Here I think that the following points matter

- The reader quickly identifies the *purpose* of the text and can relate it to questions he/she considers interesting and/or important.
- The reader faces nice figures, which relate to the main content.
- The reader is not terrified by many uncommon acronyms, a bunch of complicated formulas, long paragraphs etc.
- The reader encounters familiar works in the list of references, which indicate that the topic of the article is of relevance for him/her.

Most important is probably to present a well formulated *purpose statement* as early as possible. This is a short paragraph of text, which provides concise answers to the following questions: (the subsequent list is copied from [5])

A. What is the significance of the paper?
B. Why is it important and original?
C. Who will be interested, who is the intended audience?
D. What are the implications for practice, what are the further research questions?

[4] See www.lub.lu.se/en/services-and-activities/student-support/academic-writing/academic-integrity
[5] `http://www.emeraldgrouppublishing.com/authors/guides/write/structure.htm?part=1`

A possible setup is: i) Formulate the general vision for the research field [A,C]); ii) Address the knowledge gap or the particular challenge addressed [B]; iii) Present your solution to it ("Here we...") [A,B]; iv) Specify, how your solution can be used with respect to the vision ("This leads to...") [D]. Note that the main text must substantiate this purpose statement and should follow its logical flow.

7 Details, which frequently go wrong

Remember that you know more than the reader. Thus

- Define all quantities used (maybe except for $\hbar, c, k_B$). Which sign of e is used?
- Give all parameters used in calculations. In particular, it must be clear how the results shown in a figure are obtained (if different parameters are used, specify them in each figure caption or the figure itself). You should also motivate the values (e.g. specific references to other works, calculating them, or simply state something like "as an estimate we use"), so that the reader has a possibility to judge their validity.
- For all equations or other issues, which are not general knowledge for the standard reader of the work: Derive them or give a reference!
- Define all acronyms (such as QCL) the first time they are used in the main text (not in the abstract!). As most people have a bad memory, one should restrict to a few acronyms, which are common in the field.

Follow common typographic conventions, such as

- Use Ref. [2] with square, Eq. (2) with round and Fig. 2 or Sec. 2 without brackets.
- Use Roman font for text and units in equations: E.g. $G^{\mathrm{ret}} = \frac{1}{3\ \mathrm{meV}}$, written as `G^{\mathrm{ret}}= \frac{1}{3\textrm{ meV}}` in Latex.

Text structure

- Paragraphs should not be too short and definitely contain more than one sentence.
- Avoid sentences with more than 30-40 words. If you have forgotten the beginning while reaching the end of the sentence, it is too long!
- Lists should have at least two and at most five items. Longer lists (unless there is a clear logic in the sequence such as a recipe) are difficult to read. Group things and add some text in between as done in this section.

Grammar

- The use of articles in English is difficult for many non-native speakers. See, e.g., `https://learnenglish.britishcouncil.org/en/beginner-grammar/articles-1` or `https://owl.purdue.edu/owl/general_writing/grammar/using_articles.html`
- Native Swedish speakers: Do not forget the extra 's' at verbs in the third person singular!

8 A strategy to achieve a good treatise

Most people cannot write a good text directly from the beginning to the end. There are far too many intricate relations (e.g. the logical order of topics, motivation for different parts, changing knowledge about the field) to consider. Thus you will typically reorder the material several times, delete larger paragraphs, and writing the final text will take much longer than you originally planned. Furthermore, it is very common that one gets new insights during the process of writing as this focuses attention on the topic. Thus the following strategy can be

helpful[6]:

1. Start to write different bits and pieces in the very beginning and continue with this throughout the project. For example, in the beginning you describe the task of the project, some first thoughts to tackle it, or your motivation. Subsequently, you describe the method you use, summarize briefly relevant topics discussed in the literature, document first results with preliminary figures, and formulate working hypotheses. There is a good chance that you get new ideas while writing!
2. When you have accomplished the main part of the project, put things together (and drop some less related parts) to establish a logical structure. This structure ties your most interesting results together with the relevant theory and further data confirming the correctness and relevance of results. Here you have a first draft, which you need to discuss with all coauthors (or your supervisor). This process may need some iteration until the content is well defined. It is not uncommon, that new insights appear and further calculations/measurements are done in this phase.
3. Formulate the conclusion and the abstract and discuss this very specifically with coauthors (or supervisor).
4. Revise the text carefully, so that it points towards the conclusion. Now, you need to work very carefully on the introduction, which should in particular define the knowledge gap, which justifies the work. You might rearrange or add figures to visualize the logical flow.
5. Finally, polish the work: Check equations and consistency in the use of variables, improve the final figures, check that all abbreviations are defined, have a careful look at language issues, etc. Read these *tips for manuscripts* again, and make sure that all points are satisfied. Even in this stage you will find better ways to organize the material. Reorganize accordingly – but only if you have sufficient time to polish things again!

While you can be sloppy with formats and styles in the first two stages (you will change most parts later), be careful with three points:

- Always include the references used for the material you write about. In particular, mark text which you copied verbatim from other sources. Otherwise you may forget about it.
- Always include all parameters used for every data set you print, even if its a preliminary version of a figure!
- Always save the raw data shown in figures (and the code with input files which generated them) as you might redo the figure or wonder about further details later.

I also strongly suggest to always use a spell-checker before you give any text to coauthors/supervisor. This saves a lot of effort.

9 General aims and assessment for reports and theses

Writing a report is a part of the education, during which the student shall learn to

- retrieve and read scientific literature
- familiarize him/her-self with new topics
- structure the information found in different sources
- relate new topics to the body of knowledge taught in the course
- formulate scientific context according to common standards

In addition, for a *thesis*, original research work should be performed. This implies to

[6] A thorough argumentation for this can be found in L. Rienecker and P.S. Jørgensen *Att skriva en bra uppsats*, 4th edition (Liber, Stockholm 2012)

- recognize open questions.
- use scientific concepts to address these questions.
- assess the validity of new results. This is typically done by comparison of the outcome with established context (experimental data; study of limits, where results are known) or by making clear predictions which can verify or falsify the results in the future.
- document own research.

The assessment regards the quality of all these points. Here, one has to be aware, that the first impression is crucial. Thus you should *check particularly well* that

- the abstract and conclusion are concise and highlight the main results. They must be free from grammatical errors.
- the figures are of high quality, see above.
- the list of references is in a nice regular shape and reasonably long.

At last, a practical hint without any scientific relevance: The acknowledgment section of a thesis will be the most read part. Put some effort to create a nice text and be careful not to forget people who helped you to do the work.

10 Helpful links

The platform on Academic Writing in English at Lund University (AWELU) provides plenty of information, see `http://awelu.srv.lu.se/`. In particular have a look at

Academic Integrity `http://awelu.srv.lu.se/academic-integrity/`
Grammar `http://awelu.srv.lu.se/grammar-and-words/`

Styleguide for Physical Review `https://cdn.journals.aps.org/files/styleguide-pr.pdf`