How to Write Your Thesis

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I. Thesis structure

Title Page

Title (including subtitle), author, institution, department, date of delivery, research mentor, mentor's institution

Abstract

- A good abstract explains in one line why the paper is important. It then goes on to give a summary of your major results, preferably couched in numbers with error limits. The final sentences explain the major implications of your work. A good abstract is concise, readable, and quantitative.
- Length should be ~ 1-2 paragraphs, approx. 400 words.
- Information in title should not be repeated.
- Be explicit.
- Use numbers where appropriate.
- Answers to these questions should be found in the abstract:
    1. What did you do?
    2. Why did you do it? What question were you trying to answer?
    3. How did you do it? State methods.
    4. What did you learn? State major results.
    5. Why does it matter? Point out at least one significant implication.

Table of Contents

- list all headings and subheadings with page numbers
- indent subheadings
- it will look something like this:

Recommendations
Acknowledgments
References
Appendices

List of Figures

List page numbers of all figures.

List of Tables

List page numbers of all tables.

Introduction

You can't write a good introduction until you know what the body of the paper says. Consider writing the introductory section(s) after you have completed the rest of the paper, rather than before.

Be sure to include a hook at the beginning of the introduction. This is a statement of something sufficiently interesting to motivate your reader to read the rest of the paper, it is an important/interesting scientific problem that your paper either solves or addresses. You should draw the reader in and make them want to read the rest of the paper.

The next paragraphs in the introduction should cite previous research in this area. It should cite those who had the idea or ideas first, and should also cite those who have done the most recent and relevant work. You should then go on to explain why more work was necessary (your work, of course.)

What else belongs in the introductory section(s) of your paper?

1. A statement of the goal of the paper: why the study was undertaken, or why the paper was written. Do not repeat the abstract.
2. Sufficient background information to allow the reader to understand the context and significance of the question you are trying to address.
3. Proper acknowledgement of the previous work on which you are building. Sufficient references such that a reader could, by going to the library, achieve a sophisticated understanding of the context and significance of the question.
4. Explain the scope of your work, what will and will not be included.
5. A verbal "road map" or verbal "table of contents" guiding the reader to what lies ahead.
6. Is it obvious where introductory material ("old stuff") ends and your contribution ("new stuff") begins?

Remember that this is not a review paper. We are looking for original work and interpretation/analysis by you. Break up the introduction section into logical segments by using subheads.

Methods

What belongs in the "methods" section of a scientific paper?

1. Information to allow the reader to assess the believability of your results.
2. Information needed by another researcher to replicate your experiment.
3. Description of your materials, procedure, theory.
4. Calculations, technique, procedure, equipment, and calibration plots.
5. Limitations, assumptions, and range of validity.

The methods section should answering the following questions and caveats:

1. Could one accurately replicate the study (for example, all of the optional and adjustable parameters on any sensors or instruments that were used to acquire the data)?
2. Could another researcher accurately find and reoccupy the sampling stations or track lines?
3. Is there enough information provided about any instruments used so that a functionally equivalent instrument could be used to repeat the experiment?
4. If the data is in the public domain, could another researcher lay his or her hands on the identical data set?
5. Could one replicate any laboratory analyses that were used?
6. Could one replicate any statistical analyses?
7. Could another researcher approximately replicate the key algorithms of any computer software?

Citations in this section should be limited to data sources and references of where to find more complete descriptions of procedures.
Do not include descriptions of results.

Results

- The results are actual statements of observations, including statistics, tables and graphs.
- Indicate information on range of variation.
- Mention negative results as well as positive. Do not interpret results - save that for the discussion.
- Lay out the case as for a jury. Present sufficient details so that others can draw their own inferences and construct their own explanations.
- Use S.I. units (m, s, kg, W, etc.) throughout the thesis.
- Break up your results into logical segments by using subheads

Note: Results vs. Discussion Sections

Quarantine your observations from your interpretations. The writer must make it crystal clear to the reader which statements are observation and which are interpretation. In most circumstances, this is best accomplished by physically separating statements about new observations from statements about the meaning or significance of those observations. Alternatively, this goal can be accomplished by careful use of phrases

such as "I infer ..." vast bodies of geological literature became obsolete with the advent of plate tectonics; the papers that survived are those in which observations were presented in stand-alone fashion, unmuddied by whatever ideas the author might have had about the processes that caused the observed phenomena.

How do you do this?

1. Physical separation into different sections or paragraphs.
2. Don't overlay interpretation on top of data in figures.
3. Careful use of phrases such as "We infer that ".
4. Don't worry if "results" seem short.

Why?

1. Easier for your reader to absorb, frequent shifts of mental mode not required.
2. Ensures that your work will endure in spite of shifting paradigms.

Discussion

Start with a few sentences that summarize the most important results. The discussion section should be a brief essay in itself, answering the following questions and caveats:

1. What are the major patterns in the observations? (Refer to spatial and temporal variations.)
2. What are the relationships, trends and generalizations among the results?
3. What are the exceptions to these patterns or generalizations?
4. What are the likely causes (mechanisms) underlying these patterns resulting predictions?
5. Is there agreement or disagreement with previous work?
6. Interpret results in terms of background laid out in the introduction - what is the relationship of the present results to the original question?
7. What is the implication of the present results for other unanswered questions in earth sciences?
8. Multiple hypotheses: There are usually several possible explanations for results. Be careful to consider all of these rather than simply pushing your favorite one. If you can eliminate all but one, that is great, but often that is not possible with the data in hand. In that case you should give even treatment to the remaining possibilities, and try to indicate ways in which future work may lead to their discrimination.
9. Avoid bandwagons: A special case of the above. Avoid jumping a currently fashionable point of view unless your results really do strongly support them.
10. What are the things we now know or understand that we didn't know or understand before the present work?
11. Include the evidence or line of reasoning supporting each interpretation.
12. What is the significance of the present results: why should we care?

This section should be rich in references to similar work and background needed to interpret results. However, interpretation/discussion section(s) are often too long and

verbose. Is there material that does not contribute to one of the elements listed above? If so, this may be material that you will want to consider deleting or moving. Break up the section into logical segments by using subheads.

Conclusions

- What is the strongest and most important statement that you can make from your observations?
- If you met the reader at a meeting six months from now, what do you want them to remember about your paper?
- Refer back to problem posed, and describe the conclusions that you reached from carrying out this investigation, summarize new observations, new interpretations, and new insights that have resulted from the present work.
- Include the broader implications of your results.
- Do not repeat word for word the abstract, introduction or discussion.

Recommendations

- Remedial action to solve the problem.
- Further research to fill in gaps in our understanding.
- Directions for future investigations on this or related topics.

Acknowledgments

Advisor(s) and anyone who helped you:

1. technically (including materials, supplies)
2. intellectually (assistance, advice)
3. financially (for example, departmental support, travel grants)

References

- cite all ideas, concepts, text, data that are not your own
- if you make a statement, back it up with your own data or a reference
- all references cited in the text must be listed
- cite single-author references by the surname of the author (followed by date of the publication in parenthesis)
    - ... according to Hays (1994)
    - ... population growth is one of the greatest environmental concerns facing future generations (Hays, 1994).
- cite double-author references by the surnames of both authors (followed by date of the publication in parenthesis)
    - e.g. Simpson and Hays (1994)
- cite more than double-author references by the surname of the first author followed by et al. and then the date of the publication
    - e.g. Pfirman, Simpson and Hays would be:
    - Pfirman et al. (1994)
- do not use footnotes
- list all references cited in the text in alphabetical order using the following

format for different types of material:

- Hunt, S. (1966) Carbohydrate and amino acid composition of the egg capsules of the whelk. *Nature*, 210, 436-437.
- National Oceanic and Atmospheric Administration (1997) Commonly asked questions about ozone. http://www.noaa.gov/public-affairs/grounders/ozo1.html, 9/27/97.
- Pfirman, S.L., M. Stute, H.J. Simpson, and J. Hays (1996) Undergraduate research at Barnard and Columbia, *Journal of Research*, 11, 213-214.
- Pechenik, J.A. (1987) A short guide to writing about biology. Harper Collins Publishers, New York, 194pp.
- Pitelka, D.R., and F.M. Child (1964) Review of ciliary structure and function. In: *Biochemistry and Physiology of Protozoa*, Vol. 3 (S.H. Hutner, editor), Academic Press, New York, 131-198.
- Sambrotto, R. (1997) lecture notes, Environmental Data Analysis, Barnard College, Oct 2, 1997.
- Stute, M., J.F. Clark, P. Schlosser, W.S. Broecker, and G. Bonani (1995) A high altitude continental paleotemperature record derived from noble gases dissolved in groundwater from the San Juan Basin, New Mexico. *Quat. Res.*, 43, 209-220.
- New York Times (1/15/00) PCBs in the Hudson still an issue, A2.

- it is acceptable to put the initials of the individual authors behind their last names, e.g. Pfirman, S.L., Stute, M., Simpson, H.J., and Hays, J (1996) Undergraduate research at .....

Appendices

- Include all your data in the appendix.
- Reference data/materials not easily available (theses are used as a resource by the department and other students).
- Tables (where more than 1-2 pages).
- Calculations (where more than 1-2 pages).
- You may include a key article as appendix.
- If you consulted a large number of references but did not cite all of them, you might want to include a list of additional resource material, etc.
- List of equipment used for an experiment or details of complicated procedures.
- Note: Figures and tables, including captions, should be embedded in the text and not in an appendix, unless they are more than 1-2 pages and are not critical to your argument.

II. Crosscutting Issues

What Are We Looking For?

We are looking for a critical analysis. We want you to answer a scientific question or hypothesis. We would like you to gather evidence -- from various sources -- to allow you to make interpretations and judgments. Your approach/methods should be carefully designed to come to closure. Your results should be clearly defined and discussed in the

context of your topic. Relevant literature should be cited. You should place your analysis in a broader context, and highlight the implications (regional, global, etc.) of your work. We are looking for a well-reasoned line of argument, from your initial question, compilation of relevant evidence, setting data in a general/universal context, and finally making a judgment based on your analysis. Your thesis should be clearly written and in the format described below.

Planning Ahead for Your Thesis

If at all possible, start your thesis research during the summer between your junior and senior year - or even earlier - with an internship, etc. ... then work on filling in background material and lab work during the fall so that you're prepared to write and present your research during the spring . The best strategy is to pick a project that you are interested in, but also that a faculty member or other professional is working on. This person will become your research mentor and this gives you someone to talk with and get background material from. If you're unsure about the selection of a project, let us know and we'll try to connect you with someone.

et ideas about what you need to do and if you wait too long to write things up, you'll not have time to finish.

Writing for an Audience

Who is your audience?

1. Researchers working in analogous field areas elsewhere in the world (i.e. other strike-slip faults, other deep sea fans).
2. Researchers working in your field area, but with different techniques.
3. Researchers working on the same interval of geologic time elsewhere in the world.
4. All other researchers using the same technique you have used .
5. If your study encompasses an active process, researchers working on the same process in the ancient record.
6. Conversely, if your study is based on the rock record, people studying modem analogs.
7. People writing a synthesis paper on important new developments in your field.
8. People applying earth science to societal problems (i.e. earthquake hazard reduction, climate warming) who will try to understand your paper.
9. Potential reviewers of your ms. or your thesis committee.

Skimming vs. Reading

Because of the literature explosion, papers more skimmed than read. Skimming involves reading the abstract, and looking at the figures and figure captions. Therefore, you should construct your paper so that it can be understood by skimming, i.e., the conclusions, as written in your abstract, can be understood by study of the figures and

captions. The text fills out the details for the more interested reader.

Order of Writing

Your thesis is not written in the same order as it is presented in. The following gives you one idea how to proceed.

1. first organize your paper as a logical argument before you begin writing
2. make your figures to illustrate your argument (think skimming)
3. the main sections are: background to the argument (intro); describing the information to be used in the argument, and making points about them (observations), connecting the points regarding the info (analysis), summing up (conclusions).
4. outline the main elements: sections, and subsections
5. begin writing, choosing options in the following hierarchy - paragraphs, sentences, and words.

Here is another approach.

1. Write up a preliminary version of the background section first. This will serve as the basis for the introduction in your final paper.
2. As you collect data, write up the methods section. It is much easier to do this right after you have collected the data. Be sure to include a description of the research equipment and relevant calibration plots.
3. When you have some data, start making plots and tables of the data. These will help you to visualize the data and to see gaps in your data collection. If time permits, you should go back and fill in the gaps. You are finished when you have a set of plots that show a definite trend (or lack of a trend). Be sure to make adequate statistical tests of your results.
4. Once you have a complete set of plots and statistical tests, arrange the plots and tables in a logical order. Write figure captions for the plots and tables. As much as possible, the captions should stand alone in explaining the plots and tables. Many scientists read only the abstract, figures, figure captions, tables, table captions, and conclusions of a paper. Be sure that your figures, tables and captions are well labeled and well documented.
5. Once your plots and tables are complete, write the results section. Writing this section requires extreme discipline. You must describe your results, but you must NOT interpret them. (If good ideas occur to you at this time, save them at the bottom of the page for the discussion section.) Be factual and orderly in this section, but try not to be too dry.
6. Once you have written the results section, you can move on to the discussion section. This is usually fun to write, because now you can talk about your ideas about the data. If you can come up with a good cartoon/schematic showing your ideas, do so. Many papers are cited in the literature because they have a good cartoon that subsequent authors would like to use or modify.
7. In writing the discussion session, be sure to adequately discuss the work of other authors who collected data on the same or related scientific questions. Be sure to discuss how their work is relevant to your work. If there were flaws in their methodology, this is the place to discuss it.
8. After you have discussed the data, you can write the conclusions section. In this

section, you take the ideas that were mentioned in the discussion section and try to come to some closure. If some hypothesis can be ruled out as a result of your work, say so. If more work is needed for a definitive answer, say that.

9. The final section in the paper is a recommendation section. This is really the end of the conclusion section in a scientific paper. Make recommendations for further research or policy actions in this section. If you can make predictions about what will be found if X is true, then do so. You will get credit from later researchers for this.
10. After you have finished the recommendation section, look back at your original introduction. Your introduction should set the stage for the conclusions of the paper by laying out the ideas that you will test in the paper. Now that you know where the paper is leading, you will probably need to rewrite the introduction.
11. You must write your abstract last.

Figures and Tables

- The actual figures and tables should be embedded/inserted in the text, generally on the page following the page where the figure/table is first cited in the text.
- All figures and tables should be numbered and cited consecutively in the text as figure 1, figure 2, table 1, table 2, etc.
- Include a caption for each figure and table, citing how it was constructed (reference citations, data sources, etc.) and highlighting the key findings (think skimming). Include an index figure (map) showing and naming all locations discussed in paper.
- You are encouraged to make your own figures, including cartoons, schematics or sketches that illustrate the processes that you discuss. Examine your figures with these questions in mind:
    1. Is the figure self-explanatory?
    2. Are your axes labeled and are the units indicated?
    3. Show the uncertainty in your data with error bars.
    4. If the data are fit by a curve, indicate the goodness of fit.
    5. Could chart junk be eliminated?
    6. Could non-data ink be eliminated?
    7. Could redundant data ink be eliminated?
    8. Could data density be increased by eliminating non-data bearing space?
    9. Is this a sparse data set that could better be expressed as a table?
    10. Does the figure distort the data in any way?
    11. Are the data presented in context?
    12. Does the figure caption guide the reader's eye to the "take-home lesson" of the figure?
- Figures should be oriented vertically, in portrait mode, wherever possible. If you must orient them horizontally, in landscape mode, orient them so that you can read them from the right, not from the left, where the binding will be.

Tying the Text to the Data

"Show them, don't just tell them…" Ideally, every result claimed in the text should be

documented with data, usually data presented in tables or figures. If there are no data provided to support a given statement of result or observation, consider adding more data, or deleting the unsupported "observation."
Examine figure(s) or table(s) pertaining to the result(s).
Assess whether:

1. the data support the textual statement
2. the data contradict the textual statement
3. the data are insufficient to prove or refute the textual statement
4. the data may support the textual statement, but are not presented in such a way that you can be sure you are seeing the same phenomenon in the data that the author claims to have seen.

Giving Credit

How does one fairly and accurately indicate who has made what contributions towards the results and interpretations presented in your paper?: by referencing, authorship, and acknowledgements.
Different types of errors:

1. direct quotes or illustrations without quotation marks, without attribution
2. direct quotes without quotation marks, with attribution
3. concepts/ideas without attribution
4. concepts/ideas with sloppy attribution
5. omitting or fabricating data or results

Check references carefully and reread reference works prior to publication. The first time you read something, you will consciously remember some things, but may subconsciously take in other aspects. It is important to cross check your conscious memory against your citations.
See also:
D. Kennedy, 1985, On Academic Authorship
Sigma Xi, 1984, Honor in Science
Yale University pamphlet on plagiarism

Final Thesis

- Make 3 final copies: 1 to mentor and 2 to department, so that we can have 2 readers.
- Final thesis should be bound.
- Printed cleanly on white paper.
- Double-spaced using 12-point font.
- 1-inch margins.
- Double-sided saves paper.
- Include page numbers.

Resources

- The Barnard Writing Room provides assistance on writing senior theses.
- Look at other theses on file in the Environmental Science department, they will give you an idea of what we are looking for.
- Of course do not hesitate to ask us, or your research advisor for help.
- The Barnard Environmental Science Department has many books on scientific writing, ask the departmental administrator for assistance in locating them.
- Also see additional books listed as Resources.

III. Editing Your Thesis

Even a rough draft should be edited.

Copy Editing

1. Proof read your thesis a few times.
2. Check your spelling. spellcheckers are useful for initial checking, but don't catch homonyms (e.g. hear, here), so you need to do the final check by eye.
3. Make sure that you use complete sentences
4. Check your grammar: punctuation, sentence structure, subject-verb agreement (plural or singular), tense consistency, etc.
5. Give it to others to read and comment.

Content Editing

1. logic
2. repetition, relevance
3. style

Avoiding ambiguity

1. Do not allow run-on sentences to sneak into your writing; try semicolons.
2. Avoid nested clauses/phrases.
3. Avoid clauses or phrases with more than two ideas in them.
4. Do not use double negatives.
5. Do not use dangling participles (i.e. phrases with an "-ing" verb, in sentences where the agent performing the action of the "-ing" verb is not specified: " After standing in boiling water for two hours, examine the flask.").
6. Make sure that the antecedent for every pronoun (it, these, those, that, this, one) is crystal clear. If in doubt, use the noun rather than the pronoun, even if the resulting sentence seems a little bit redundant.
7. Ensure that subject and verb agree in number (singular versus plural).
8. Be especially careful with compound subjects. Be especially careful with subject/verb agreement within clauses.
9. Avoid qualitative adjectives when describing concepts that are quantifiable ("The water is deep." "Plate convergence is fast." "Our algorithm is better.") Instead, quantify. ("Water depths exceed 5km.")
10. Avoid noun strings ("acoustic noise source location technique").

11. Do not use unexplained acronyms. Spell out all acronyms the first time that you use them.

Thesis length

Write for brevity rather than length. The goal is the shortest possible paper that contains all information necessary to describe the work and support the interpretation. Avoid unnecessary repetition and irrelevant tangents.
Necessary repetition: the main theme should be developed in the introduction as a motivation or working hypothesis. It is then developed in the main body of the paper, and mentioned again in the discussion section (and, of course, in the abstract and conclusions).
Some suggestions on how to shorten your paper:

1. Use tables for repetitive information.
2. Include only sufficient background material to permit the reader to understand your story, not every paper ever written on the subject.
3. Use figure captions effectively.
4. Don't describe the contents of the figures and/or tables in the text item-by-item. Instead, use the text to point out the most significant patterns, items or trends in the figures and tables.
5. Delete "observations" or "results" that are mentioned in the text for which you have not shown data.
6. Delete "conclusions" that are not directly supported by your observations or results.
7. Delete "interpretation" or "discussion" sections that are inconclusive.
8. Delete "interpretation" or "discussion" sections that are only peripherally related to your new results or observations.
9. Scrutinize adjectives! adverbs and prepositional phrases.

Although it varies considerably from project to project, average thesis length is about 40 pages of text plus figures. This total page count includes all your text as well as the list of references, but it does not include any appendices. These generalizations should not be taken too seriously, especially if you are working on a labor-intensive lab project. If you have any questions about whether your project is of sufficient scope, consult one of us early on.

Writing for an International Audience

1. Put as much information as possible into figures and tables. In particular, try to find a way to put your conclusions into a figure, perhaps a flowchart or a cartoon.
2. Don't assume that readers are familiar with the geography or the stratigraphy of your field area.
3. Every single place-name mentioned in the text should be shown on a map.
4. Consider including a location map, either as a separate figure or as an inset to another figure. If your paper involves stratigraphy, consider including a summary stratigraphic column--in effect, a location map in time.

5. Use shorter sentences. Avoid nested clauses or phrases.
6. Avoid idioms. Favor usages that can be looked up in an ordinary dictionary. "Take the beaker out of the oven immediately..." rather than "Take the beaker out of the oven right away..."

Last Updated : 09/23/2004 14:29:37*by:* *martins@ldeo.columbia.edu*