How to Write a Research Thesis

InterAmerican University

Getting Started

When you are about to begin, writing a thesis seems a long, difficult task. That is because it is a long, difficult task. Fortunately, it will seem less daunting once you have a couple of chapters done. Towards the end, you will even find yourself enjoying it---an enjoyment based on satisfaction in the achievement, pleasure in the improvement in your technical writing, and of course the approaching end. Like many tasks, thesis writing usually seems worst before you begin, so let us look at how you should make a start.

An outline

First make up a thesis outline: several pages containing chapter headings, sub-headings, some figure titles (to indicate which results go where) and perhaps some other notes and comments. There is a section on chapter order and thesis structure at the end of this text. Once you have a list of chapters and, under each chapter heading, a reasonably complete list of things to be reported or explained, you have struck a great blow against writer's block. When you sit down to type, your aim is no longer a thesis -a daunting goal- but something simpler. Your new aim is just to write a paragraph or section about one of your subheadings. It helps to start with an easy one: this gets you into the habit of writing and gives you self-confidence. Often the Materials and Methods chapter is the easiest to write -just write down what you did-; carefully, formally and in a logical order.

How do you make an outline of a chapter? For most of them, you might try the method that is usually used for writing papers: assemble all the figures that you will use in it and put them in the order that you would use if you were going to explain to someone what they all meant. You might as well rehearse explaining it to someone else -after all you will probably give several talks based on your thesis work-. Once you have found the most logical order, note down the key words of your explanation. These key words provide a skeleton for much of your chapter outline.

Once you have an outline, discuss it with your Thesis Director. This step is important: s/he will have useful suggestions, but it also serves notice that s/he can expect a steady flow of chapter drafts that will make high priority demands on his/her time. Once you and your Director have agreed on a logical structure, s/he will need a copy of this outline for reference when reading the chapters which you will probably present out of order. If you have a co-Director, discuss the outline with him/her as well, and present all chapters to both Directors for comments.

Organization

It is encouraging and helpful to start a filing system. Open a word-processor file for each chapter *and one for the references.* You can put notes in these files, as well as text. While doing something for Chapter n, you will think "Oh I must refer back to/discuss this in Chapter m" and so you put a note to do so in the file for Chapter m. Or you may think of something interesting or relevant for that chapter. When you come to work on Chapter m, the more such notes you have accumulated, the easier it will be to write.

Make a back-up of these files and do so every day at least (depending on the reliability of your computer and the age of your disk drive). Do not keep back-up disks close to the computer in case the hypothetical thief who fancies your computer decides that s/he could use some disks as well.

A simple way of making a remote back-up is to send it as an email attachment to a consenting email correspondent, preferably one in a different location. You could even send it to yourself if your server saves your mail (in some email packages like Eudora this is an optional setting). In either case, be careful to dispose of superseded versions so that you don't waste disk space, especially if you have bitmap images or other large files.

You should also have a physical filing system: a collection of folders with chapter numbers on them. This will make you feel good about getting started and also help clean up your desk. Your files will contain not just the plots of results and pages of calculations, but all sorts of old notes, references, calibration curves, suppliers' addresses, specifications, speculations, letters from colleagues etc., which will suddenly strike you as relevant to one chapter or other. Stick them in that folder. Then put all the folders in a box or a filing cabinet. As you write bits and pieces of text, place the hard copy, the figures etc in these folders as well. Touch them and feel their thickness from time to time -ah, the thesis is taking shape-.

If any of your data exist only on paper, copy them and keep the copy in a different location. Consider making a copy of your lab book. This has another purpose beyond security: usually the lab book stays in the lab, but you may want a copy for your own future use. Further, scientific ethics require you to keep lab books and original data for at least ten years, and a copy is more likely to be found if two copies exist.

While you are getting organized, you should deal with any university paperwork. Examiners have to be nominated and they have to agree to serve. Various forms are required by your department and by the university administration. Make sure that the rate limiting step is your production of the thesis, and not some minor bureaucratic problem.

A note about word processors

One of the big FAQs for scientists: is there a word processor, ideally MS Word or one compatible with MS Word but, for instance, which allows you to type mathematical symbols and equations conveniently? One solution is LaTeX, which is powerful, elegant, reliable, fast and *free* from http://www.latex-project.org/ or http://www.miktex.org/. An alternative is to use old versions of commercial software. Word 5.1 allows equations to be typed without touching the mouse and is as fast in this respect as LaTeX, with the added advantage of 'what you see is what you get'. A search will find sites that provide discontinued software, but, not knowing whether this is legal or not, it would not be recommendable to link to them.

Commercial word processors have gradually become bigger, slower, less reliable and more awkward to use as they acquire more features. This is a general feature of commercial

software and an important input to the computing industry. If software and operating system performance did not deteriorate, people would not need to buy new computers and profits would fall for makers of both hard- and soft-ware. Software vendors want it to look fancy and obvious in the demo, and they don't really care about its ease, speed and reliability to an expert user because the expert user has already bought it. In our example, it is much faster to type equations and to do formatting with embedded commands because you use your fingers independently rather than your hand and because your fingers don't leave the keyboard. However, click-on menus, although they are slow and cumbersome when typing, look easy to use in the shop.

A timetable

We strongly recommend sitting down with the Director and making up a timetable for writing it: a list of dates for when you will give the first and second drafts of each chapter to your Director(s). This structures your time and provides intermediate targets. If you merely aim "to have the whole thing done by [some distant date]", you can deceive yourself and procrastinate more easily. If you have told your Director that you will deliver a first draft of chapter 3 on Wednesday, it focuses your attention.

You may want to make your timetable into a chart with items that you can check off as you have finished them. This is particularly useful towards the end of the thesis when you find there will be quite a few loose ends here and there.

Iterative solution

Whenever you sit down to write, it is very important to write *something.* So write something, even if it is just a set of notes or a few paragraphs of text that you would never show to anyone else. It would be nice if clear, precise prose leapt easily from the keyboard, but it usually does not. Most of us find it easier, however, to improve something that is already written than to produce text from nothing. So put down a draft (as rough as you like) for your own purposes, then clean it up for your Director to read. Word-processors are wonderful in this regard: in the first draft you do not have to start at the beginning, you can leave gaps, you can put in little notes to yourself, and then you can clean it all up later.

Your Director will expect to read each chapter in draft form. S/he will then return it to you with suggestions and comments. *Do not be upset if a chapter -specially the first one you write- returns covered in red ink.* Your Director will want your thesis to be as good as possible, because his/her reputation as well as yours is affected. Scientific writing is a difficult art, and it takes a while to learn. As a consequence, there will be many ways in which your first draft can be improved. So take a positive attitude to all the scribbles with which your Director decorates your text: each comment tells you a way in which you can make your thesis better.

As you write your thesis, your scientific writing is almost certain to improve. Even for native speakers of English who write very well in other styles, one notices an enormous improvement in the first drafts from the first to the last chapter written. The process of

writing the thesis is like a course in scientific writing, and in that sense each chapter is like an assignment in which you are taught, but not assessed. Remember, only the final draft is assessed: the more comments your Director adds to first or second draft, the better.

Before you submit a draft to your Director, run a spell check so that s/he does not waste time on those. If you have any characteristic grammatical failings, check for them.

What is a thesis? For whom is it written? How should it be written?

Your thesis is a research report. The report concerns a problem or series of problems in your area of research and ***it should describe what was known about it previously, what you did towards solving it, what you think your results mean, and where or how further progress in the field can be made***. Do not carry over your ideas from undergraduate assessment: a thesis is not an answer to an assignment question. One important difference is this: the reader of an assignment is usually the one who has set it. S/he already knows the answer (or one of the answers), not to mention the background, the literature, the assumptions and theories and the strengths and weaknesses of them. The readers of a thesis do not know what the "answer" is. If the thesis is for a PhD, the university requires that it make an original contribution to human knowledge: your research must discover something hitherto unknown.

Obviously your examiners will read the thesis. They will be experts in the general field of your thesis but, on the exact topic of your thesis, you are the world expert. Keep this in mind: you should write to make the topic clear to a reader who has not spent most of the last three years thinking about it.

Your thesis will also be used as a scientific report and consulted by future professionals interested in your area of expertise who will want to know, in detail, what you did. Theses are occasionally consulted by people from other institutions, and the library can send microfilm versions if requested (yes, still). More and more theses are now stored in an entirely digital form (i.e. the figures as well as the text are on a disk). A consequence of this is that your thesis can be consulted much more easily by researchers around the world. Write with these possibilities in mind.

It is often helpful to have someone other than your Director(s) read some sections of the thesis, particularly the introduction and conclusion chapters. It may also be appropriate to ask other members of staff to read some sections of the thesis which they may find relevant or of interest, as they may be able to make valuable contributions. In either case, only give them revised versions, so that they do not waste time correcting your grammar, spelling, poor construction or presentation.

How much detail?

The short answer is: rather more than for a scientific paper. Once your thesis has been assessed and your friends have read the first three pages, the only further readers are likely to be people who are seriously doing research in just that area. For example, a future research student might be pursuing the same research and be interested to find out exactly what you did. For example, in the case of important parts of apparatus, you should include workshop drawings, circuit diagrams and computer programs, usually as appendices. (By the way, the intelligible annotation of programs is about as frequent as porcine aviation, but it is far more desirable. You wrote that line of code for a reason: at the end of the line explain what the reason is.) You have probably read the theses of previous students in the lab where you are now working, so you probably know the advantages of a clearly explained, explicit thesis and/or the disadvantages of a vague one.

Make it clear what is yours

If you use a result, observation or generalization that is not your own, you must usually state where in the scientific literature that result is reported. The only exceptions are cases where every researcher in the field already knows it: for instance, dynamics equations need not be followed by a citation of Newton, circuit analysis does not need a reference to Kirchoff. The importance of this practice in science is that it allows the reader to verify your starting position. In many cases, results are built upon results which in turn are built upon results etc. Good referencing allows us to check the foundations of your additions to the structure of knowledge in the discipline, or at least to trace them back to a level which we judge to be reliable. Good referencing also tells the reader which parts of the thesis are descriptions of previous knowledge and which parts are your additions to that knowledge. In a thesis, written for the general reader who has little familiarity with the literature of the field, this should be especially clear. It may seem tempting to leave out a reference in the hope that a reader will think that a nice idea or an nice bit of analysis is yours. I advise against this gamble. The reader will probably think: "What a nice idea -I wonder if it's original?-". The reader can probably find out via the library, the net or even just from a phone call.

If you are writing in the passive voice, you must be more careful about attribution than if you are writing in the active voice. "The sample was prepared by heating yttrium..." does not make it clear whether you did this or whether Acme Yttrium did it. "I prepared the sample..." is clear.

Style

The text must be clear. Good grammar and thoughtful writing will make the thesis easier to read. Scientific writing has to be a little formal---more formal than this text. Native English speakers should remember that scientific English is an international language. Slang and informal writing will be harder for a non-native speaker to understand.

Short, simple phrases and words are often better than long ones. Some politicians use "at this point in time" instead of "now" precisely because it takes longer to convey the same meaning. They do not care about elegance or efficient communication. You should. On the other hand, there will be times when you need a complicated sentence because the idea is complicated. If your primary statement requires several qualifications, each of these may need a subordinate clause: "When [qualification], and where [proviso], and if [condition] then [statement]". Some lengthy technical words will also be necessary in many theses, particularly in fields like biochemistry. Do not sacrifice accuracy for the sake of brevity. "Black is white" is simple and catchy. An advertising copy writer would love it. "Objects of very different albedo may be illuminated differently so as to produce similar reflected spectra" is longer and uses less common words, but, compared to the former example, it has the advantage of being true. The longer example would be fine in a physics thesis because English speaking physicists will not have trouble with the words. (A PhD candidate who did not know all of those words would probably be glad to remedy the lacuna either from the context or by consulting a dictionary.)

Sometimes it is easier to present information and arguments as a series of numbered points, rather than as one or more long and awkward paragraphs. A list of points is usually easier to write. You should be careful not to use this presentation too much: your thesis must be a connected, convincing argument, not just a list of facts and observations.

One important stylistic choice is between the active voice and passive voice. The active voice ("I measured the frequency...") is simpler, and it makes clear what you did and what was done by others. The passive voice ("The frequency was measured...") makes it easier to write ungrammatical or awkward sentences. If you use the passive voice, be especially wary of dangling participles. For example, the sentence "After considering all of these possible materials, plutonium was selected" implicitly attributes consciousness to plutonium. This choice is a question of taste: I prefer the active because it is clearer, more logical and makes attribution simple. The only arguments I have ever heard for avoiding the active voice in a thesis are (i) many theses are written in the passive voice, and (ii) some very polite people find the use of "I" immodest. Use the first person singular, not plural, when reporting work that you did yourself: the editorial 'we' may suggest that you had help beyond that listed in your acknowledgments, or it may suggest that you are trying to share any blame. On the other hand, retain plural verbs for "data": "data" is the plural of "datum", and lots of scientists like to preserve the distinction. Just say to yourself "one datum is ..", "these data are.." several times. An excellent and widely used reference for English grammar and style is *A Dictionary of Modern English Usage* by H.W. Fowler.

Presentation

There is no need for a thesis to be a masterpiece of desk-top publishing. Your time can be more productively spent improving the content than the appearance.

In many cases, a reasonably neat diagram can be drawn by hand faster than with a graphics package. Either is usually satisfactory. The computer-generated figure has the advantage that it can be stored in the text and transmitted electronically, but this advantage disappears

if you are not going to store your thesis as a file for transmission. You can scan a hand drawn figure. As a one bit, moderate resolution graphic, it will probably not be huge, but it will still be bigger than a line drawing generated on a graphics package.

In general, students spend too much time on diagrams---time that could have been spent on examining the arguments, making the explanations clearer, thinking more about the significance and checking for errors in the algebra. The reason, of course, is that drawing is easier than thinking.

I do not think that there is a strong correlation (either way) between length and quality. There is no need to leave big gaps to make the thesis thicker. Readers will not appreciate large amounts of vague or unnecessary text.

Approaching the end

A deadline is very useful in some ways. You must hand in the thesis, even if you think that you need one more draft of that chapter, or someone else's comments on this section, or some other refinement. If you do not have a deadline, or if you are thinking about postponing it, please take note of this: *A thesis is a very large work. It cannot be made perfect in a finite time*. There will inevitably be things in it that you could have done better. There will be inevitably be some typos. Indeed, by some law related to Murphy's, you will discover one when you first flip open the bound copy. No matter how much you reflect and how many times you proof read it, there will be some things that could be improved. There is no point hoping that the examiners will not notice: many examiners feel obliged to find some examples of improvements (if not outright errors) just to show how thoroughly they have read it. So set yourself a deadline and stick to it. Make it as good as you can in that time, and then hand it in! (In retrospect, there was an advantage in writing a thesis in the days before word processors, spelling checkers and typing programs. Students often paid a typist to produce the final draft and could only afford to do that once.)

How many copies?

Talk to your Director about this. As well as those for the examiners, the university library, the registry and yourself, you should make some distribution copies, all of them, of course, duly bound. These copies should be sent to other researchers who are working in your field so that:

- they can discover what marvellous work you have been doing before it appears in journals;
- they can look up the fine details of methods and results that will or have been published more briefly elsewhere;
- they can realize what an excellent researcher you are. This realization could be useful if a post- doctoral position were available in their labs. soon after your submission, or if they were reviewers of your research/post-doctoral proposal. Even having your name in their bookcases might be an advantage.

Whatever the University's policy on single or double-sided copies, the distribution copies could be double-sided so that forests and postage accounts are not excessively depleted by the exercise. Your Director could help you to make up a list of interested and/or potentially useful people for such a mailing list. Your Director might also help by funding the copies and postage if they are not covered by your scholarship.

The following comment comes from a recent PhD candidate: "When I finished writing my thesis, a postdoc wisely told me to give a copy to my parents. I would never have thought of doing that as I just couldn't imagine what they would do with it. I'm very glad to have taken that advice as my parents really appreciated receiving a copy and proudly displayed it for years. (My mother never finished high school and my father worked with trucks - he fixed 'em, built 'em, drove 'em, sold 'em and junked 'em. Nevertheless, they enjoyed having a copy of my thesis.)"

Personal

In the ideal situation, you will be able to spend a large part---perhaps a majority -of your time writing your thesis-. This may be bad for your physical and mental health.

Typing

Set up your chair and computer properly. The Health Service, professional keyboard users or perhaps even the school safety officer will be able to supply charts showing recommended relative heights, healthy postures and also exercises that you should do if you spend a lot of time at the keyboard. These last are worthwhile insurance: you do not want the extra hassle of back or neck pain. Try to intersperse long sessions of typing with other tasks, such as reading, drawing, calculating, thinking or doing research.

If you do not touch type, you should learn to do so for the sake of your neck as well as for productivity. There are several good software packages that teach touch typing interactively. If you use one for say 30 minutes a day for a couple of weeks, you will be able to touch type. By the time you finish the thesis, you will be able to touch type quickly and accurately and your six hour investment will have paid for itself. Be careful not to use the typing exercises as a displacement activity.

Exercise

Do not give up exercise for the interim. Lack of exercise makes you feel bad, and you do not need anything else making you feel bad while writing a thesis. 30-60 minutes of exercise per day is probably not time lost from your thesis: I find that if I do not get regular exercise, I sleep less soundly and longer. How about walking to work and home again? (Walk part of the way if your home is distant.) Many people opine that a walk helps them think, or clears the head. You may find that an occasional stroll improves your productivity.

Food

Do not forget to eat, and make an effort to eat healthy food. You should not lose fitness or risk illness at this critical time. Exercise is good for keeping you appetite at a healthy level. I know that you have little time for cooking, but keep a supply of fresh fruit, vegetables and bread. It takes less time to make a sandwich than to go to the local fast food outlet, and you will feel better afterwards.

Drugs

Thesis writers have a long tradition of using coffee as a stimulant and alcohol or marijuana as relaxants. (Use of alcohol and coffee is legal, use of marijuana is not.) Used in moderation, they do not seem to have ill effects on the quality of thesis produced. Excesses, however, are obviously counter-productive: several expressi and you will be buzzing too much to sit down and work; several drinks at night will slow you down next day.

Others

Other people will be sympathetic, but do not take them for granted. Spouses, lovers, family and friends should not be undervalued. Spend some time with them and, when you do, have a good time. Do not spend your time together complaining about your thesis: they already resent the thesis because it is keeping you away from them. If you can find another student writing a thesis, then you may find it therapeutic to complain to each other about Directors and difficulties. S/he need not be in the same discipline as you are.

Coda

Keep going -you're nearly there-! Most PhDs will admit that there were times when we thought about reasons for not finishing. But it would be crazy to give up at the writing stage, after years of work on the research, and it would be something to regret for a long time.

Writing a thesis is tough work. One anonymous post doctoral researcher once said: "You should tell everyone that it's going to be unpleasant, that it will mess up their lives, that they will have to give up their friends and their social lives for a while. It's a tough period for almost every student." She's right: it is certainly hard work, it will probably be stressful and you will have to adapt your rhythm to it. It is also an important rite of passage and the satisfaction you will feel afterwards is wonderful. On behalf of scholars everywhere, we all wish you good luck!

A suggested thesis structure

The list of contents and chapter headings below is appropriate for some theses. In some cases, one or two of them may be irrelevant. Results and Discussion are usually combined in several chapters of a thesis. Think about the plan of chapters and decide what is best to report your work. Then make a list, in point form, of what will go in each chapter. Try to make this rather detailed, so that you end up with a list of points that corresponds to subsections or even to the paragraphs of your thesis. At this stage, think hard about the logic of the presentation: within chapters, it is often possible to present the ideas in different order, and not all arrangements will be equally easy to follow. If you make a plan of each chapter and section before you sit down to write, the result will probably be clearer and easier to read. It will also be easier to write.

Copyright waiver

Our institution has a form for this. In any case, this standard page gives the university library the right to publish the work, possibly by microfilm or some other medium. (At IAU, the Postgraduate Student Office offers you this thesis pack with various guide-lines and rules about thesis format. Make sure that you consult that for its formal requirements, as well as this rather informal guide.)

Declaration

Check the wording required by IAU, and whether there is a standard form. Many universities require something like: "I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text. (signature/name/date)"

Title page

This may vary among institutions, but as an example: Title/author/"A thesis submitted for the degree of Doctor of Philosophy in the College/School of Science/InterAmerican University"/date.

Abstract

Of all your thesis, this part will be the most widely published and most read because it will be published in Dissertation Abstracts International. It is best written towards the end, but not at the very last minute because you will probably need several drafts. It should be a distillation of the thesis: a concise description of the problem(s) addressed, your method of solving it/them, your results and conclusions. An abstract must be self-contained. Usually they do not contain references. When a reference is necessary, its details should be included in the text of the abstract. Check the word limit.

Acknowledgments

Most thesis authors put in a page of thanks to those who have helped them in matters scientific, and also indirectly by providing such essentials as food, education, genes, money, help, advice, friendship etc. *If any of your work is collaborative, you should make it quite clear who did which sections.*

Table of contents

The introduction starts on page 1, the earlier pages should have roman numerals. It helps to have the subheadings of each chapter, as well as the chapter titles. Remember that the thesis may be used as a reference in the lab, so it helps to be able to find things easily.

Introduction

What is the topic and why is it important? State the problem(s) as simply as you can. Remember that you have been working on this project for a few years, so you will be very close to it. Try to step back mentally and take a broader view of the problem. How does it fit into the broader world of your discipline?

Especially in the introduction, do not overestimate the reader's familiarity with your topic. You are writing for researchers in the general area, but not all of them need be specialists in your particular topic. It may help to imagine such a person -think of some researcher whom you might have met at a conference for your subject, but who was working in a different area-. S/he is intelligent, has the same general background, but knows little of the literature or tricks that apply to your particular topic.

The introduction should be interesting. If you bore the reader here, then you are unlikely to revive his/her interest in the materials and methods section. For the first paragraph or two, tradition permits prose that is less dry than the scientific norm. If want to wax lyrical about your topic, here is the place to do it. Try to make the reader want to read the pound of A4 or letter size that has arrived uninvited on his/her desk. Go to the library and read several thesis introductions. Did any make you want to read on? Which ones were boring?

This section might go through several drafts to make it read well and logically, while keeping it short. For this section, I think that it is a good idea to ask someone who is not a specialist to read it and to comment. Is it an adequate introduction? Is it easy to follow? There is an argument for writing this section -or least making a major revision of it- towards the end of the thesis writing. Your introduction should tell where the thesis is going, and this may become clearer during the writing.

Literature review

Where did the problem come from? What is already known about this problem? What other methods have been tried to solve it?

Ideally, you will already have much of the hard work done, if you have been keeping up with the literature as you vowed to do three years ago, and if you have made notes about important papers over the years. If you have summarised those papers, then you have some good starting points for the review.

How many papers? How relevant do they have to be before you include them? Well, that is a matter of judgement. On the order of a hundred is reasonable, but it will depend on the field. You are the world expert on the (narrow) topic of your thesis: you must demonstrate this.

A political point: make sure that you do not omit relevant papers by researchers who are like to be your examiners, or by potential employers to whom you might be sending the thesis in the next year or two.

Middle chapters

In some theses, the middle chapters are the journal articles of which the student was major author. There are several disadvantages to this format.

One is that a thesis is both allowed and expected to have more detail than a journal article. For journal articles, one usually has to reduce the number of figures. In many cases, all of the interesting and relevant data can go in the thesis, and not just those which appeared in the journal. The degree of experimental detail is usually greater in a thesis. Relatively often a researcher requests a thesis in order to obtain more detail about how a study was performed.

Another disadvantage is that your journal articles may have some common material in the introduction and the "Materials and Methods" sections.

The exact structure in the middle chapters will vary among theses. In some theses, it is necessary to establish some theory, to describe the experimental techniques, then to report what was done on several different problems or different stages of the problem, and then finally to present a model or a new theory based on the new work. For such a thesis, the chapter headings might be: Theory, Materials and Methods, {first problem}, {second problem}, {third problem}, {proposed theory/model} and then the conclusion chapter. For other theses, it might be appropriate to discuss different techniques in different chapters, rather than to have a single Materials and Methods chapter.

Here follow some comments on the elements Materials and Methods, Theory, Results and discussion which may or may not correspond to thesis chapters.

Materials and Methods

This varies enormously from thesis to thesis, and may be absent in theoretical theses. It should be possible for a competent researcher to reproduce exactly what you have done by following your description. There is a good chance that this test will be applied: sometime

after you have left, another researcher will want to do a similar experiment either with your gear, or on a new set-up in a foreign country. Please write for the benefit of that researcher.

In some theses, particularly multi-disciplinary or developmental ones, there may be more than one such chapter. In this case, the different disciplines should be indicated in the chapter titles.

Theory

When you are reporting theoretical work that is not original, you will usually need to include sufficient material to allow the reader to understand the arguments used and their physical bases. Sometimes you will be able to present the theory *ab initio,* but you should not reproduce two pages of algebra that the reader could find in a standard text. Do not include theory that you are not going to relate to the work you have done.

When writing this section, concentrate at least as much on the physical arguments as on the equations. What do the equations mean? What are the important cases?

When you are reporting your own theoretical work, you must include rather more detail, but you should consider moving lengthy derivations to appendices. Think too about the order and style of presentation: the order in which you did the work may not be the clearest presentation.

Suspense is not necessary in reporting science: you should tell the reader where you are going before you start.

Results and discussion

The results and discussion are very often combined in theses. This is sensible because of the length of a thesis: you may have several chapters of results and, if you wait till they are all presented before you begin discussion, the reader may have difficulty remembering what you are talking about. The division of Results and Discussion material into chapters is usually best done according to subject matter.

Make sure that you have described the conditions which obtained for each set of results. What was held constant? What were the other relevant parameters? Make sure too that you have used appropriate statistical analyses. Where applicable, show measurement errors and standard errors on the graphs. Use appropriate statistical tests.

Take care plotting graphs. The origin and intercepts are often important so, unless the ranges of your data make it impractical, the zeros of one or both scales should usually appear on the graph. You should show error bars on the data, unless the errors are very small. For single measurements, the bars should be your best estimate of the experimental errors in each coordinate. For multiple measurements these should include the standard error in the data. The errors in different data are often different, so, where this is the case, regressions and fits should be weighted (i.e. they should minimize the sum of squares of the differences weighted inversely as the size of the errors.) (A common failing in many simple

software packages that draw graphs and do regressions is that they do not treat errors adequately.

Try to distance yourself from your usual perspective and look at your work. Do not just ask yourself what it means in terms of the orthodoxy of your own research group, but also how other people in the field might see it. Does it have any implications that do not relate to the questions that you set out to answer?

Final chapter, references and appendices

Conclusions and suggestions for further work

Your abstract should include your conclusions in very brief form, because it must also include some other material. A summary of conclusions is usually longer than the final section of the abstract, and you have the space to be more explicit and more careful with qualifications. You might find it helpful to put your conclusions in point form.

It is often the case with scientific research that more questions than answers are produced. Does your work suggest any interesting further avenues? Are there ways in which your work could be improved by future workers? What are the practical implications of your work?

This chapter should usually be reasonably short---a few pages perhaps. As with the introduction, I think that it is a good idea to ask someone who is not a specialist to read this section and to comment.

References (See also under literature review)

It is tempting to omit the titles of the articles cited, and the university allows this, but think of all the times when you have seen a reference in a paper and gone to look it up only to find that it was not helpful after all.

Appendices

If there is material that should be in the thesis but which would break up the flow or bore the reader unbearably, include it as an appendix. Some things which are typically included in appendices are: important and original computer programs, data files that are too large to be represented simply in the results chapters, pictures or diagrams of results which are not important enough to keep in the main text.

As a Conclussion:

Just keep in mind the following instructions, that are presented in a comprehensive, step-by-step sequence for your convenience:

I. Thesis structure

Title Page

Title (including subtitle), author, institution, department, date of delivery, research director, director'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:

Page #

List of Figures
List of Tables
Introduction
    subheads ...?
Methods
    subheads ...?
Results
    subheads ...?
Discussion

subheads ...?

Conclusions

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.

Proper acknowledgement of the previous work on which you are building.

(3) 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:

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)?

Could another researcher accurately find and reoccupy the sampling stations or track lines?

Is there enough information provided about any instruments used so that a functionally equivalent instrument could be used to repeat the experiment?

If the data is in the public domain, could another researcher lay his or her hands on the identical data set?

Could one replicate any laboratory analyses that were used?

Could one replicate any statistical analyses?

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.

Do not use footnotes.

In your reference list, only list references cited in text.

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 (Hays, 1994).

Cite double-author references by the surnames of both authors (followed by date of the publication in parenthesis)

... 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)

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.

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 immediately after your Master's degree -or even earlier- with an internship, *etc*. ... then work on filling in background material and lab work during the fall (through Environmental Research 3997x) 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 director 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.

Start writing as soon as possible, background, methods, results, discussion/interpretations ... as you write you will get 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.

Final Thesis

Make 3 final copies: 1 to director 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

IAU provides assistance on writing senior theses.

If you need it, ask for assistance, an expert 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.

IAU has many books on scientific writing, ask the relevant departmental administrator for assistance in locating them.

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) Make sure that the antecedent for every pronoun is clear.

(7) In some languages, a pronoun used as the subject of a sentence is required to refer to the subject of the previous sentence. In other languages, a pronoun is required to refer to the most recently occurring noun. In English, either usage is permitted, which leaves ample room for confusion.

(8) Use words that have cognates in other languages; usually these are Latin-derived words.

(9) 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..."

(10) Many English words have many different meanings. Avoid using words in their more obscure meanings. Most English dictionaries list the multiple meanings of words in order from most common to least common. Try to stick with the first few meanings. The less common meanings may not occur in the translation dictionary that your reader may be using.

(11) Avoid using nouns as adjectives. For example: "mudslide advisory panel." This construction is not allowed in some languages; in other languages the ending of the noun is changed to indicate that it is being used as an adjective.

(12) Avoid words that sound similar in different languages but have subtly different meanings: "actual", "actuel" (French and German): French and German word means "of the present time, contemporary ." The primary meaning of the English word is "existing in reality; not merely possible, but real. "