How to write a ...

LAB REPORT

... for Bio 4422

This document is the result of several years experience in writing scientific reports. Its main purpose is to be helpful to students, so if you have any comments or criticism that might help me make it better, please let me know! wang@cl.uh.edu

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THE 'HOW TO' ...

General overview - What information goes where?

The different sections of a scientific paper / lab report correspond to the 'mental steps' you have to go through when you do and analyze an experiment. They therefore also correspond to the individual steps in the scientific method. I have tried to (very loosely) summarize what belongs in each section, and which step of the scientific method it corresponds to in Table 1.

Table 1: What information goes where in a lab report, and which step in the scientific method does each section correspond to?

<table>
<tr><th>Section</th><th>Contains info on...</th><th>Step of Scientific Method</th></tr>
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The way marks are distributed across these sections in Bio 4422 reflects their relative importance and should give you a basic idea of how much of your time to put into each - Introductions, for example, are important, but don't get hung up here if you are pressed for time - it is more important to put some thought into the Discussion!

Individual Sections

Title Information

The following title information should be on the first page of your lab report:

- Your name
- The date
- Your lab section
- The title of the paper (see below)

The title should be centered at the top of the cover page, followed by your name, date, and lab section.
Titles - The title you give your paper should be **INFORMATIVE** ('The influence of concentraion on pH value' is NOT a good title). Your title should tell the reader what your paper is about. It should say which type of organism you studied, what you did to it, and what you measured. (All this does NOT mean that your title has to be four lines long!)

Some **examples** for descriptive titles are given below.

- Effect of ErbB2 Coexpression on the Kinetic Interactions of Epidermal Growth Factor with Its Receptor in Intact Cells
- An Interdomain Linker Increases the Thermostability and Decreases the Calcium Affinity of the Calmodulin N-Domain
- Carboxypeptidase E, a Prohormone Sorting Receptor, Is Anchored to Secretory Granules via a C-Terminal Transmembrane Insertion

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Abstract

The abstract generally summarizes the background of the field you study and what have been done in the report

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Introduction

The introduction should, as the term implies, introduce the reader to the subject. It should give him/her the information he/she needs in order to understand what you are about to do and why you are doing it. This means you have to:

- **<u>Define any terms that your reader may not be familiar with</u>**. - If your paper is on DNA electrophoresis, explain what DNA electrophoresis is in your introduction
- **<u>Give some background information</u>**. This generally takes the form of a short review of the literature on the subject. 'Literature review' does not mean that you have to read every word that has ever been written on your subject. - The objective here is not to bombard your reader with unnecessary information, but to give them some background information to tell them where your study fits in.

- **<u>Tell your reader why your work is important</u>**. The introduction is supposed to get people interested - you don't want to leave them with a feeling of 'OK, so buffer is important for biological system, but why should I care?' So basically, if what you are looking at in your lab report has some direct practical application or relevance to people, mention it. (A quick word of caution though: stick to your facts and stay objective - a lab report is NOT a moralistic statement or political document.)

One last thing the Introduction should contain is your **Experimental Hypothesis**. Clearly state what you think will happen. In the Discussion, you will later evaluate your results with respect to whether or not they support the hypothesis stated in the Introduction.

Materials and Methods

This section explains the methodology you used in your study (i.e. how exactly you did your experiment). It should be written so that someone else can re-do the experiment based on your description. If you were writing this section yourself, you would use past tense. The methodology you used is explained in great detail in the lab manual or handout, and all you have to do is refer your reader to it. The only exception to this rule is when you deviated from the lab manual procedure - If what you did is DIFFERENT from what the manual says, mention the change in procedure in the Materials and Methods section.

Results

Ok - this is where we get into all the **FUN** stuff!

This section is where you summarize the results of your study. Data can be presented in a variety of different formats, and the use of tables and figures is generally encouraged if they help to summarize your data and to show up some of the trends in it. (This is also the section where you would talk about your statistics, if you had done any). The one thing I feel I can't say often is that **the main body of your Results section consists of WRITTEN TEXT.** Tables and figures are included to support what you are saying and elaborate on some of the details. All your main findings, however, should be verbally summarized within the text, so that your reader knows what the results are without ever looking at tables or figures.

All this means that writing a Results section is probably not one of the most exciting things to do. Because there is a set way of doing it, however, it should be something you can almost do in your sleep once you get the hang of it. Here are some basic tips on how to approach it:

<u>1) Do not INTERPRET your data</u>

(you will have plenty of room for that in the Discussion). Imagine, for example, you did an experiment that involved extracting photosynthetic pigments from different groups of algae. Your results indicate that:

Green algae contain pigments of type A, B & C.
Brown algae contain pigments of type A, C & D.
Red algae contain pigments of type A, D & F.
When you talk about this, you can organize it in various different ways: You can say:

> Green algae were found to contain pigments of type A, B, and C. Brown algae were found to contain pigments of type A, C and D, and red algae ..... (I am sure you get the idea).

This gets rather repetitive, and it may be more informative to **summarize** the information into something like:

> All three types of algae were found to contain pigments of type A. Pigments of type B were only found in green algae, whereas pigments of type C were found in both green and brown algae, and pigments of type D were found in both brown and red algae....

All this basically describes what you found - and that is what you are supposed to do in the Results section. DO NOT draw conclusions such as 'The fact that pigments of type C were found in both green and brown algae but not in red algae *suggests that green and brown algae are evolutionarily more closely related to each other than either of them is to red algae*'. This is an interpretation of your results and inappropriate in this section.

2) If appropriate, use subheadings.

In most labs you have to write up, you will be looking at several things at once: Several environmental variables, several different species, several different points in time, etc. When it comes to writing your Results section, it may help you to organize your thoughts (and your writing) if you organize your data into corresponding sections, and use appropriate subheadings.

For example: In your experiments on enzymes, you will learn how to isolate and purify enzymes, how to quantify the enzyme and what the enzymatic kinetic looks like, etc. In you lab report, you cannot write them up in one paragraph, instead, you have to describe these experiments in subgroups. Organizing your data this way makes it a lot easier for the reader to follow what you are saying, and it also makes it a lot easier to refer back to the Results section at a later stage in order to find a specific bit of information.

The one thing you have to be careful with when using subheadings is AVOID OVERDOING THEM. Having five subheadings, each of them with only one or two sentences underneath them, breaks up the flow of the paper more than is necessary and does not increase readability.

3) Move from the general to the specific.

That means state overall similarities first (if there are any) and move on to small differences later. When talking about morphological features, for example, you may want to move from large to small (i.e. talk about overall body plan before you start going into details about the attachment of toenails). How exactly you do this will depend on each specific case and on the data you are presenting.

4) Figures and Tables

Figures and tables are an important part of your Results section. They back up and expand on what you said in the text. Most problems in lab reports that relate to figures and tables are not related to content, but rather to format. There are some basic conventions relating to the numbering, referral to and titles of figures and tables in scientific papers. Whether these make sense to you or not, you have to get used to them ....and follow them!.

Numbering

Figures and tables are numbered independently using Arabic (i.e. our normal) numbers. That means that if you have both figures and tables in your report, your first figure will be **Figure 1**, the second figure will be **Figure 2**, ...etc. Your first table will be **Table 1**, the second table will be **Table 2**, ...etc.

Titles

In addition to its number (Figure 1, Table 5), each figure and table should have a title. Convention dictates that

- **Table** titles are placed **above** the actual table
- **Figure** titles are placed **below** the actual figure

Both figure and table titles should be descriptive and self-explanatory. - They should give the reader a complete picture of what is shown in the figure or table (i.e. it should be possible to understand what a figure / table shows just by looking at it and reading the title - without referring back to the actual text.)
Examples:

- Bad table title: Table 1: Leaf area data
- Good table title: Table 1: Leaf areas measured in sun and shade plants of English ivy (*Hedera* sp.)
- Bad figure title: Figure 1: Light versus depth
- Good figure title: Figure 1: Change in light intensity measured over a depth gradient in Clear Lake, Houston, Texas.

Referrals from Text
Every figure or table you put into your lab report has to be referred to from somewhere within the text! This goes back to the idea that figures and tables are basically there to back up what you are saying in the text. The way you do this is fairly straightforward: Within the text, figures and tables are referred to by their number:

Examples are shown in the attached articles.

Discussion
The Discussion of your lab report is where you get to go into the 'What it all means' - i.e. this is where you get to interpret your data, and where you are supposed to put your results into a wider context. This is the section where you have the most 'creative freedom' to take the subject wherever you think is important. The point I am trying to make is that the format for a Discussion is probably less rigid than that for most of the other sections of a lab report. There are, however, some things you have to do in this section:

<u>1) Evaluate your experimental hypothesis in the light of the data you collected.</u>

The best way of doing this (and, *hint*, an almost foolproof way of beginning a discussion) is to broadly summarize your results (again) in the first sentence(s) (different to your abstract by rephrasing your sentences), and then to say whether these findings support or contradict your hypothesis:

NMR titration curves reveal that *P. hollandica* Pc and *Ph.laminosum* cyt*f* form a complex of 1:1 stoichiometry with a binding affinity of 6 ((2) _ 10^3 M^{-1}, about 20-fold higher than that of the physiological Pc (Figure 6). Chemical-shift perturbation mapping implies that the hydrophobic patch of Pc dominates the complex interface (Figure 8). This suggests that *P. hollandica* Pc utilizes a “head-on” interaction to maximize hydrophobic contacts with cyt*f*, similar to the complex formed between *Ph. laminosum* Pc and cyt*f* (Figure 1) (10).
Or:
NMR titration curves do not indicate that *P. hollandica* Pc and *Ph.laminosum* cyt*f* form a complex of 1:1 stoichiometry ….., …. We therefore reject our hypothesis ….

NOTE: Never say that the results of your study *prove* your hypothesis. Hypotheses, by definition, can only be *disproved.* This is actually intuitively understandable if you think about it: Imagine you start out with the hypothesis that

Cholesterol levels are higher in men than in women.

Following good scientific method, you would now design an experiment to test this hypothesis. If your male test subjects turn out to have, on average, higher cholesterol levels than your female test subjects and statistical analysis of your data indicates that males have significantly higher cholesteral levels than females, you could say that your results support your hypothesis. They don't prove it, however, because there is a possibility that other researcher in Nowhereville does a similar experiment and finds the opposite.

For example, there is always the possibility that the hypothesis is false in a specific case. If, on the other hand, your experiment shows that there is no significant difference in cholesterol levels between males and females (or those of females are higher), that would disprove your original hypothesis. However, you probably would not phrase it like this in your report - we generally talk about rejecting hypotheses.

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2) Explain wacky results

If your results contradict your hypothesis, or you have other unexpected results, try to explain what could have caused this. - *Why did the experiment not 'behave' the way you thought it would?* There are two broad categories of explanation you could launch into:

- **Experimental Error.** This is a big one, and the likely cause for lots of wacky results, at least in your immediate future as scientists. Thinking about experimental error goes into the whole theory of experimental design: What could go wrong at various stages in the experiment? Which environmental variables did we not control for? Where did we mess up in the method? .... The list of possibilities is endless. If you can figure out what could have gone wrong in an experiment to produce the results you observed, that usually shows the reader (and the person who is grading your report) that you understand the mechanics of the experiment and knew what you were doing!
- **The real world...** Not all strange results are attributable to experimental error. There is always the possibility that the hypothesis you started with is simply WRONG. - A lot of the greatest discoveries in science have been the result of 'failed' experiments, which forced researchers to reject their previous notion of 'how things work' and to come up with alternative explanations. If you decide that your original hypothesis was wrong, try to come up with an alternative hypothesis that would fit the results of your study. (The next step would then be to test the new hypothesis - but you don't generally get to do that while you are a student.)

In general (at least when it comes to lab reports) there is no such thing as bad data. If your results are rather unexpected and show the opposite of what the textbook says, you will have to do some explaining, but you don't automatically fail!

3) Elaborate

In this case, 'elaborate' means 'discuss your results'. Questions you may want to consider include:

- How do these results relate to established knowledge? (Use literature to back up what you are saying)
- What implications do they have? (in terms of scientific theory, management, conservation - whichever applies to the subject you are studying)

- What should be done next? - In many cases, the results of an experiment lead to new questions, and a good thing to do in a Discussion is to suggest what could be investigated next.

Anyway, there are number of 'ways you can go' in a Discussion.

Conclusion

I prefer to think of this as a SUMMARY, rather than a Conclusion. You should not really say anything in this section that you have not said before. The conclusion should be brief (usually no more than one paragraph), and it should restate (yet again)

- What you did
- What you found
- Some implication of the results

  That does not mean you have to repeat everything you just said. The Conclusion should be brief and to the point. An example is shown in the chopped article.

Literature Cited and use of literature throughout the paper

This is one of the 'biggies' in terms of problems that consistently appear in student lab reports. Within a scientific paper or lab report literature is used and referred to in a very specific way. As with most of the rules for scientific writing, you may find this hard to get used to at first but trust me, once you get used to it anything else will soon feel awkward and impractical. If you are doing a science degree you will do best if you get used to the 'scientific format' NOW (or else it will haunt you for years to come). If you are an arts major you still have to use this format in Biol 4422, but I suggest you check with your professor before you use it in something like an English essay!

What do I mean when I say…..

- **Within-text citation.** This refers to the type of citation you use when you refer to an item of literature (e.g., your textbook, a journal article, the lab handout) in the main text of your report. The format of within-text citations tends to be very brief, as their main purpose is to refer to the item in a way that allows the reader to look up the full citation in the literature cited section of the report.
- **Full citation.** The full citation for an item of literature has to be listed within the literature cited section of your report. It contains all the information necessary to find this particular bit of literature in a library. The format used depends on whether you are referring to a book, a journal article, etc.

When do I refer to literature?

In general, you should use literature to (a) back up what you are saying whenever you use ideas that are not your own, or (b) support ideas that you cannot expect the average person to know. The first of these is relatively easy to understand: an idea (or information) that is not your own is one that you have found in a journal article, textbook, etc., and that you are using in your report. This includes situations such as:

- You are writing your enzymes lab report, and you found a journal article that talks about a similar experiment. You mention the article and some of the conclusions that the authors drew from their results in your report.

In this situation, you directly incorporated ideas or information from the literature into your report, and you should give the original source credit by correctly referring to it.
The decision of when a piece of information needs to be backed up with literature simply because the 'average person' (whoever that may be) would not know about it is a lot less clear-cut. In general, whenever you define a term or mention a concept that you would not have known about before you started writing this paper, back it up by referring to the lab handout, the textbook, or any other published source of information. I realize that you know about a lot of things because you learnt about them in school or at university, and you cannot necessarily remember where you first learnt about them or refer to a primary source for that information. That is OK for the time being - but you should get into the habit of referring to some sort of authority when you make statements that are not intuitively obvious to the average person on the street.