EFFECTIVE LABORATORY REPORTS

A Guide for Laboratory Report Writing for Students in the Biotechnology Laboratory Technician Program

Mary Ellen Kraus, Ph.D.
Madison Area Technical College
Fall 2003

EFFECTIVE LABORATORY REPORTS

Table of Contents

EFFECTIVE LABORATORY REPORTS

The ability to write a good laboratory report is an essential skill for all scientists. For many students, however, producing a well-written lab report is a laborious task. Here, I hope to present some useful pointers on lab report writing, and a discussion of lab report content so that you will have a clear idea of my expectations from your written work.

General characteristics of a "good" lab report

One problem that some students experience when beginning to write lab reports is a vague understanding of the characteristics of a "good" report. Let us first consider some very general characteristics. A well-written lab report will be grammatically correct and free of typographical errors. Poor typing and poor grammar may seem to be trivial in comparison to the scientific content of your paper. After all, you are here to learn science, not English composition. The truth is that it is virtually impossible for a reader to ignore basic errors in spelling or grammar. At the very least, these errors are distracting. They also indicate to the reader, whether it be the instructor assigning your grade or the employer assigning your performance rating, that you believe that writing your report is not worth the time it takes for you to do the job correctly. At the very worst, these errors make it impossible for the reader to understand the work you completed and its significance.

A well-written laboratory report will be:

- ***Grammatically correct***
- ***Free of typographical errors***
- ***Concise***
- ***Easily understood by the reader***

A well-written lab report will also be concise. Some students may be skeptical about this statement. Certainly, in some academic situations it may seem that the grade received for a written assignment is proportional to the quantity, rather than the quality of the work turned in. Not so for the lab report. Your lab report should be ONLY as long as is needed to fulfill the requirements discussed later in this paper.

Finally, a lab report must be easily understood by the reader. This may seem obvious, but is not trivial to achieve. You must consider that your audience did NOT perform the experiments you did, did not read the protocols or background material that you covered, and may not be familiar enough with the work you have done to draw their own conclusions from the results that you have presented. In fact, when writing lab reports in this course, you should not assume that I am your audience. After all, I was with you in lab, I prepared the background material for you, and I have graded lab reports on these experiments from many other students in the past. Therefore, I am NOT a typical audience for your work. Instead, you should write your lab reports for an audience that is scientifically knowledgeable, but no more so than you were when you first read the protocol and background material for a given laboratory.

The parts of a laboratory report and their purposes

Every laboratory report you will write for me will contain five parts. Some reports for other courses may contain several extra sections. For this course, laboratory reports will contain a title, an introduction, a materials and methods section, a results section, and a discussion. Each section has a clearly defined purpose. If you keep this purpose in mind while writing a particular section, you will be more likely to include the information needed to make your report understandable.

The title is the first thing that a reader sees. It is also the part of the lab report that will appear in a table of contents or other document that may include your report. Therefore, the purpose of the title is to briefly describe the work investigated in the report.

Every laboratory report will contain:

- ***A title***
- ***An introduction***
- ***A materials and methods section***
- ***A results section***
- ***A discussion***

The introduction is the section of the lab report that will tell your reader what your lab report is going to investigate, how the topic will be investigated, and why you should care.

The materials and methods section tells your reader what experiments you did in your laboratory, and how you carried them out.

The results section provides the data that you collected in your experiments, and describes the relevance of your data.

The discussion section describes what you expected to see in your experiments, what you actually observed, and addresses any differences between the two. It will also relate your results and conclusions to the goals that you set out in your introduction.

The effective title

An effective laboratory report title is not necessarily brief. Not is it often "catchy" or "clever". Remember that the purpose of the title is to DESCRIBE the work presented in the report. Therefore, when writing a title you want to include enough information to set your report apart from the other, often similar, work that is out there. For instance, if you performed a set of experiments investigating the ways in which hazardous chemicals can be spread around the laboratory in aerosol form for the purpose of designing safe handling procedures your title might be something like:

An effective title is *DESCRIPTIVE* and *CONCISE*,

not

VAGUE and SHORT.

Safe handling procedures to minimize the spread of hazardous chemicals by reducing the production of aerosols.

This title tells you that the goal of the report is to develop safety protocols (as opposed to simply describing how chemicals are spread around the lab), that those protocols will deal will hazardous chemicals (as opposed to biohazardous materials), and that you are dealing specifically with the production of aerosols (as opposed to corrosives, flammable materials, etc).

The temptation is strong to make the title very brief and general. For instance, you might want to title the above work "Safe handling of hazardous chemicals". But this title is too vague because your work deals ONLY with aerosols. Remember that your title should be DESCRIPTIVE and concise, *NOT SHORT*. And, under no conditions is a title along the lines of "Laboratory Report One"acceptable!!

Writing a meaningful introduction

The introduction is an enormously important section of any laboratory report. It is also often the hardest one to write because it can be difficult to know what information is appropriate to include in an introduction.

In fact, as you gain experience writing laboratory reports, this section will become the one that varies most among individuals because the flexibility in the content that can be included in an introduction. For now, I will discuss the most general and essential information that should be included in an introduction.

An effective introduction will include:

- ***A statement of experimental goals***
- ***A description of the experimental plan***
- ***Background information as necessary for the reader to understand the report***
- ***A discussion of the relevance of the experiments***

Remember that, in most cases, the introduction will be the first information that a reader sees concerning a given set of experiments. That is, the reader will not be familiar with the protocols and background information with which you have been provided in class. Therefore, the introduction should clearly state the goals that a set of experiments are designed to meet. These goals will often be outlined in the protocols that you are provided in class. The introduction should also give the reader an outline of the experimental plan that will be followed to achieve these goals. You will give a detailed set of experimental instructions in the methods section. But often a reader will skip the methods section unless they are actually going to reproduce your work. Therefore, the reader will expect to see a general experimental plan presented in the introduction.

While you are describing your experimental plan, you should keep in mind that your reader is probably not as familiar with this area as you are. Therefore, you should include background information about concepts and terminology as necessary to satisfy the general reader. To help you choose the appropriate material, take notes about ideas and terms that are vague to you AS YOU FIRST READ THE PROTOCOLS AND

BACKGROUND MATERIAL FOR A GIVEN LABORATORY. These details that are vague or unclear to you may be ones that you want to clarify in your introduction. Remember that you must properly reference all concepts and terms. If you did not develop a plan, protocol, or concept yourself, you need to give appropriate credit to the source from which you obtained the information.

Now you are almost done with your introduction. You have described your experimental goals, plan, and provided necessary background information (properly referenced!), Lastly, you should discuss the RELEVANCE of the work you are presented. That is, why should the reader care about all of this? Ideally, before you ever run a set of experiments, you will understand why those experiments are important. In the workplace, you should never do experiments "just for the heck of it". Experiments cost money, both in supplies and in time spent by the investigator. If you don't know why it is important to run a set of experiments, research or ask!

Appendix A of this document is a brief worksheet you may want to use to gather the information for an introduction to any lab report. I suggest filling out this worksheet while you are reading through the materials for a new lab, before you ever actually get into lab. Not only will this practice give you a head start in your lab report writing, but it will also help you formulate questions you have about the lab early. If you ask questions before you begin your experimental work, you will get more out of your time in lab, be more efficient, and make fewer mistakes!

Appendix B is a checklist that you can review when you have written the first draft of your introduction. It is designed to help you avoid some of the most common errors students make when writing introductions.

Writing a reproducible methods section

The purpose of your materials and methods section is to permit the reader to exactly REPRODUCE what you did in lab. In your introduction, you will have outlined the experimental plan that you followed. However, you will not have included nearly enough information to allow the reader to copy your work. The quality of your methods section is tied to the quality of your lab notebook. Many students leave the completion of their notebook entries until days (or even longer) after they have completed the work in lab. This is extremely poor practice. You will find it impossible to keep an accurate record of your work in lab unless you write in your notebook as you do the experiments. When you are working in the biotech industry, poor record keeping will affect your co-workers, the performance of your company, and, of course, your performance rating. In this class, it will affect your grade. You should NOT assume that I will skim the methods section and, therefore, am less likely to catch errors or omissions. Writing your methods section is not difficult; however, it is

The materials and methods section should contain all information necessary for the reader to *EXACTLY REPRODUCE* the experiments described.

tedious. I encourage you to work on this section in small pieces. Spread out the experiments that you did over several days so that you do not leave information out in your haste to get your report done at the last moment!

What sorts of information should be included in your methods section? Again, you must include enough information that the reader could repeat what you did in lab. Some pieces of information that should be included, but are frequently omitted by students are:

- *Exact chemical names, the supplier (for instance, Promega), lot number, concentration, mass or volume of a solution or chemical used*

- *Equipment including make and model (for instance, a Beckman Ultracentrifuge, rather than a "centrifuge"), types of tubes (polypropylene, polystyrene, glass, eppendorf, test tube, conical tube etc), sizes of pipets or needles and similar information*

- *Conditions of centrifuge spins including type of centrifuge and rotor, X g, temperature of spin*

- *Incubation times, temperatures and conditions (heat block, water bath, with or without agitation)*

- *Gel running times, distances, voltages or current*

- *Experimental conditions, including use of hood or safety equipment*

Once you have complete writing your methods section, review it as if you are going to go into lab and follow this protocol you have written. Clarify any questions that come up as you go through the protocols in your mind.
What style should you use when writing the methods section? The methods section should be written in paragraph form in complete sentences. You should not just copy a protocol into your lab report. Protocols are usually written in the form of step-wise commands as in:

1. ***Label two microfuge tubes.***
2. ***To each tube add 0.5 mL of 1 N NaOH***
3. ***To each tube add 0.2 mL of 10% SDS***
4. ***Mix each tube by gentle inversion***

The methods section for the above protocol would be written in one of two ways, depending upon the preference of your instructor. In either case, though, the methods section would be written in paragraph form in past tense. One option is to write in first person as follows:

- ***We labeled two microfuge tubes. To each tube we added 0.5 mL of 1 N NaOH. We then added 0.2 mL of 10% SDS to each tube. We mixed both tubes by gentle inversion.***

The second option is to write the methods section in third person, passive voice as follows:

- ***Two microfuge tubes were labeled. To each tube, 0.5 mL of 1 N NaOH was added. 0.2 mL of 10% SDS was then added to each tube. Each tube was then mixed by gentle inversion.***

Appendix C is a checklist that you can review after writing a methods section to be sure that you have followed the appropriate style and form.

Writing a clear, well-organized results section

Your results section is essentially the nuts and bolts of what you did in lab. You should include all the data that you gathered in lab. This includes data that you gathered from experiments that were flawed and needed to be repeated. Your data must be clearly presented and organized. Often data will be best presented in the forms of Tables or Graphs. Sometimes you will include photographs and other types of data.

In all cases, your data must be clearly labeled. Tables must have clear, descriptive column headings, including units, where applicable. Graphs must have clear labels for the axes, again including units. When photographs are included, arrows or other marks should be used as necessary to point out important details.

When a results section has been well-written, the knowledgeable reader will be able to skim the section and have an understanding of what the results mean. Therefore, in addition to clear presentation, data should have a brief description of the significance of the data. Suppose, for instance, that you are presenting a graph showing the elution profile of column being used for protein purification. You are assessing the presence of protein by measuring the absorbance at 280 nm. Your data might be a graph of absorbance vs. elution volume. Your legend might read:

- ***"This graph shows the relationship between absorbance of various column fraction at 280 nm and fraction number. There is a clear peak of absorbance in fractions 15 through 18, representing the presence of purified protein in these fractions."***

The results section should include:

- ***All data gathered in the experiment***
- ***Titles for all charts, graphs and data***
- ***A short description of the MEANING of the data***

When you have completed writing your results section, you may want to use Appendix D as a checklist to be sure you have included all necessary information.

Writing a well-designed and informative discussion

The discussion section is probably the second most challenging section of the lab report to write, after the introduction. The discussion section is often written as an afterthought. Many students write discussions that are a paragraph or less in length, in the belief that the results section is self-explanatory. But you should NOT assume that the reader has drawn the conclusions you wish them to draw from reading the results section. In your discussion you should satisfy the following goals:

- *To explain what the results observed mean*
- *To explain any reasons that the results observed do not match expectations*
- *To discuss how the results obtained satisfy the goals delineated in the introduction*

This last goal ensures that your discussion section will be complementary to your introduction, and will help with the overall flow of your document.

Appendix E is a worksheet that is designed to help you document and organize the information you should include in your introduction. Your discussion will be complete when you have discussed all of your results, explained any discrepancies between observed results and what you expected to see, described the relevance of your findings, and related your results to the goals that you laid out in your introduction.

The discussion section explains the *significance* of your data and relates the data to the *experimental goals* of the laboratory.

Remember, when writing your discussion, do not leave it to the reader to draw conclusions. Tell the reader what your results are and be specific about what those results mean. Mention particular data in your discussion and be explicit about the relevance of that data.

Writing laboratory reports is a skill that WILL improve with practice. Leave yourself enough time to carefully organize your thoughts and data. Try not to write your entire report at one time, and do not leave research on background information to the last minute. And lastly, take the time to proofread your document before turning it in. If you are patient and budget your time, you should see that each lab report that you complete will be better than your last one!

APPENDIX A: ***INFORMATION GATHERING WORKSHEET FOR WRITING INTRODUCTIONS TO LABORATORY REPORTS***

TITLE OF REPORT: _____

_____

Part I: The *goals* of this experiment are:

_____

_____

_____

_____

Part II: The *experimental plan* that I will follow to accomplish these goals is:

_____

_____

_____

_____

_____

_____

_____

_____

Part III: Questions that I have about the *goals* of this lab (concepts or terminology) are:

_____

_____

_____

_____

Part IV: Questions that I have about the *experimental protocols* (theory or practice) are:

_____

_____

_____

_____

Part V: The reason(s) that the goals and results of this lab are important is:

_____

_____

_____

_____

APPENDIX B: ***A CHECKLIST TO AVOID COMMON ERRORS IN WRITING INTRODUCTIONS TO LABORATORY REPORTS***

TITLE OF REPORT: _____

_____

Criteria	***Yes***	***No***
I have clearly defined the *goals* of this lab		
I have clearly explained the general *experimental protocol* of this lab		
I have provided *background information* to address questions that a reader might have about the goals of this lab		
I have provided *background information* to address questions the reader might have about the experimental protocol for this lab		
I have explained the *relevance* of this lab in a larger context than simply this course		

APPENDIX C: ***A CHECKLIST TO AVOID COMMON ERRORS IN WRITING MATERIALS AND METHODS SECTIONS IN LABORATORY REPORTS***

TITLE OF REPORT: _____

_____

Criteria	***Yes***	***No***
I have included methods for ALL of the experiments performed in this lab		
I have included complete chemical names, concentrations, volumes or masses used, lot numbers, chemical suppliers		
I have included the names of all types and models of equipment used		
I have described experimental conditions such as temperature, incubation times and conditions, gel running times and voltages, centrifuge spin speeds and times, etc.		
I have discussed any special safety equipment of practices used		
I have written this section in paragraph form		
I have written this section in past tense		
I have separated separate protocols and provided headings such as “Bacterial transformation”, “Preparation of competent cells”, “Restriction digestion” etc.		
I have written consistently in either first person, or third person passive voice, depending upon the directions of my instructor		

APPENDIX D: ***A CHECKLIST TO AVOID COMMON ERRORS IN WRITING RESULTS SECTIONS IN LABORATORY REPORTS***

TITLE OF REPORT: _____

_____

Criteria	***Yes***	***No***
I have included ALL data collected for ALL of the experiments performed in this lab		
I have supplied TITLES for all graphs, tables, photos and other data included in this report		
I have clearly labeled the columns in all tables, including units		
I have clearly labeled the axes in all graphs, including units		
I have provided marks such as arrows to point out important details in all photos and similar data		
I have provided legends for data describing the significance of the data for this laboratory report		

APPENDIX E: ***A WORKSHEET TO GATHER INFORMATION FOR WRITING LABORATORY REPORT DISCUSSION SECTIONS***

Part One: Analysis of results

Result observed:_____

_____

Results expected:_____

_____

Reasons for any discrepancies:_____

_____

_____

Significance of this result:_____

_____

Result observed:_____

_____

Results
expected:_____

_____

Reasons for any
discrepancies:_____

_____

_____

Significance of this
result:_____

_____

Result
observed:_____

_____

Results
expected:_____

_____

Reasons for any
discrepancies:_____

_____

_____

Significance of this
result:_____

_____

Result
observed:_____

_____

Results
expected:_____

_____

Reasons for any
discrepancies:_____

_____

_____

Significance of this
result:_____

_____

Part Two: Linking results to experimental goals

Goal (listed in introduction):_____

_____

How did I achieve this goal through my experimental plan?_____

_____

_____

If I did not achieve this goal, how could I alter my protocol or experimental plan to better pursue this goal?

_____

_____

_____

_____

Goal (listed in introduction):_____

_____

How did I achieve this goal through my experimental plan?_____

_____

_____

If I did not achieve this goal, how could I alter my protocol or experimental plan to better pursue this goal?_____

_____

_____

_____

Goal (listed in introduction):_____

_____

How did I achieve this goal through my experimental plan?_____

_____

_____

If I did not achieve this goal, how could I alter my protocol or experimental plan to better pursue this goal?_____

_____

_____

_____
