Writing a Lab Report

Why bother to write a lab report? A lab report is the student equivalent of a scientific journal article, which is the main way that new scientific information is communicated to others. Scientific findings are worthless if they're not published—or if the paper is so dull or difficult to understand that the reader doesn't recognize the value of the results. Writing lab reports will help you in writing (and reading) real scientific papers.

A formal lab report is written just as if it were an actual scientific paper reporting on research results. The best way to learn about the style of a research paper is to *read* research papers: look carefully at a few papers from good journals before you start writing your own. Pay particular attention to the *style* of the journal articles, and try to emulate it.

This section is intended to give you a general format for a formal lab report. In some courses, your instructor may give you specific directions that supercede the general information given here, so be sure to consult your course syllabus as well. Be sure your paper precisely follows the standards given below or by your instructor; failure to follow instructions is an easy way to throw away points!

Research articles are usually divided into several sections: **Abstract**, **Introduction**, **Materials and Methods**, **Results**, **Discussion** and **References**. The order and format of these sections may vary a little between journals, but you can expect to see them in some form. You should follow this format for your lab report, and include these six sections in the order given. Please pay close attention to the instructions below, including the ***exact*** style for formatting references. Your paper will lose points if the style and formatting are not correct and might even be returned to you for re-formatting. Use the checklist at the end of this section (page 27) to help make sure your paper is correct and complete. Following the checklist, you will also find a short sample lab report.

Title

Every paper needs a title, which should give the subject of the paper without being unduly long. You can use an *informative* title, which gives the main conclusion (such as "Prolonged Water Deprivation Leads to Irreversible Dehydration in Plants") or an *indicative* one which just identifies the topic ("Effects of Water Deprivation on House Plants"). Either way, it should be *specific*. "Water" or "Experiment 6" or even "Enzyme Activity" is too general. Below the title, list the names of everyone who contributed to the project (your lab group, in this case). Place an asterisk after your name to indicate that you are the principal author of the paper. If this paper were being submitted for publication, this is the author that would correspond with the journal and have the major responsibility for its accuracy.

Abstract

The abstract is a very short statement intended to summarize the paper's main points. It is often written *after* the rest of the paper, because sometimes your major conclusions develop during the course of writing the paper. Remember that this is a *summary*, <u>not</u> an introduction. It must therefore include your results and conclusions. The abstract should be thorough enough that a reader who read *only* the abstract would still get the main idea of your paper, but it should be very compact and concise. Keep your abstract under 100 words. Place the abstract after the title (with no sub-heading) and single-space it.

Introduction

The Introduction should catch your reader's interest, explain *why* you did the experiments, and provide the background necessary to understand the rest of the paper. In writing the introduction, assume that your reader has a good general knowledge of basic biology, but not a specific knowledge of your topic. Any fellow biology major, for example, should be able to read and thoroughly understand your introduction, whether or not he/she has had the course you are writing it for. (In fact, it's a good idea to ask a friend to read your paper and point out anything that isn't perfectly clear!)

It's common to write the introduction in a sort of "pyramid" or "funnel" style. First, give a few lines of very general background in the area of your experiment, such as, say, the inheritance of eye color (but even though it's general, it should still be scientific—don't start with purple prose about which eye colors are the most romantic!). Then, spend a little longer talking about the specific background related to your research: genes known to contribute to eye color, what part of the eye is pigmented, etc. Next, specifically introduce the rationale for the experiments <u>you</u> did and briefly explain what those experiments were. Don't include any results in the introduction, but be sure someone who read <u>only</u> the introduction would still get a good picture of what you were doing.

The introduction is also where you would put your hypothesis or hypotheses. A good hypothesis never comes "out of the blue;" it is based on what you already know about the topic. So, don't forget to include the rationale for your hypothesis; often, this comes naturally from giving background information on your topic. Here is an example:

> Smith and Jones (1923) previously showed that chemical reactions happen faster at higher temperatures. However, it is also clear that enzymes can be denatured when the temperature is high enough to break non-covalent bonds (Smythe *et al*., 1947). We investigated the effect of heat on the activity of chocolatase; we hypothesize that its activity will increase as temperature increases up to some optimum point and then decrease as the three-dimensional structure of the protein is affected. We expect this optimum temperature to be around 30°C, the normal body temperature of the chocolate-munching skink (*Skinkus chocomunchii*) from which the enzyme was extracted.

Most of the Introduction should be written in present tense. It's a little hard to get used to how verb tenses are used in scientific papers, but there is a definite style which is considered appropriate. As a rule of thumb, if you're writing about well-known facts and general information, use the present tense ("The sun **is** a big ball of gas."). If you're describing a particular result from someone else's experiments, use past tense ("Johnson and Smith **found** that the sun contains hydrogen.") When you're writing about your actual experiments and results, use the past tense ("These experiments **were** designed to identify gasses in the sun; we **found** that hydrogen is a major component.").

In the Introduction (and throughout the paper), *any* information which does not come directly from your <u>own</u> experiments needs to have an appropriate **citation** to identify its source (the format is detailedin the Finding and Citing Sources section, p. 39). You will be relying on the work of others when you give background information, and giving proper credit is essential—otherwise, you have plagiarized and may be subject to disciplinary action. You should <u>paraphrase</u> all source material in *your own* words; direct quotations are ***not*** appropriate in scientific writing unless there is some very strong reason for using the source's <u>exact</u> words. Even though the material is paraphrased, its source must always be identified by a citation. Unless instructed otherwise, do <u>not</u> use your lab manual as a background source except for information that is specific to your lab and would not be published elsewhere.

After reading your introduction, the reader should have a clear understanding of (i) the overall question your experiments are intended to address, (ii) why this question is important and interesting, and (iii) the specific hypothesis or hypotheses you are investigating.

Materials and Methods

Materials and Methods is a *very brief* summary of *how* the experiments were done. In principle, a competent investigator should be able to repeat your work by following the outline of the procedure you give in this section. However, Materials and Methods is *not* a step-by-step protocol! There is usually a paragraph or so, with a sub-heading, for each major technique used in the work; each paragraph describes a procedure in a very tight, compact way. Look at some scientific papers to see how briefly the procedure is usually summarized. Materials and Methods should be written in past tense.

Do not give a list of materials or equipment, and do not write as if you were giving instructions. Write as if you were telling someone what you did in the briefest way possible.

When your procedure follows a previously published method (or the lab manual) closely, you can outline the procedure even more briefly and give a citation. For example, "We measured protein concentration as described previously (Lowry *et al.*, 1951)." If your method varies a little from what has been published, specify the differences: "We measured protein concentration as described previously (Lowry *et al.*, 1951), except that proteins were first precipitated with 10% trichloroacetic acid." As with all other non-original material in the report, if you did not personally make up the method, it needs some kind of citation to identify its source. Citing the lab manual as the source for a procedure is appropriate in this section.

In a real scientific paper, you would not include "sample calculations," but in a student lab report it is sometimes appropriate to do so, to help your instructor decide if you interpreted the data correctly. Materials and Methods is a reasonable place to mention how you determined a rate (such as using a linear regression to generate a best-fit line) or show the equation you used to calculate a result.

Results

The results section is the "heart" of your paper: it is the most important section, because this is where you explain your actual findings. It is also where you tell the reader the "story" of your experiment: what you did, why you did it, and what happened. Although you will use tables, graphs, photographs and other visual means of presenting your results, **the Results section should be a description of your results *in words***. Imagine that you will have some readers who will read the text of your results but ignore the figures, and that other readers will look at the figures but ignore the text. Be sure both of these kinds of readers will understand your results.

Your Results section should start with a brief (one or two sentence) recap of your introduction. Imagine that the reader skipped the first two sections and started reading here: what can you tell him or her in a coupl e of sentences about what you did and why that would help make the results clear? Then, move on to telling the story of your first experiment. Do not start your Results section with a figure or table! Start by writing about your experiments in paragraph form, then direct your reader's attention to figures or tables where appropriate. Each major result should have at least a paragraph or two of text—more if necessary. The Results section is generally written in past tense. You may also want to break up the section with subheadings for each major result to help your reader follow the flow of the paper.

Most of your results should be displayed in graph or table form as well as discussed in the text. If an experiment has only a very simple result, you don't have to make a table or graph for it—for example, it would be sufficient to say "Based on the equation of our best-fit line (Figure 2), the length of the plasmid was 3,600 base-pairs," rather than making a one-line table to report this single piece of data. Similarly, you would not say "The five plasmids we examined had lengths of 3600, 4250, 8700, 1470 and 5400 base-pairs (Table 1)"—since the numbers are in the table, just say "We determined the lengths of the five plasmids (Table 1)."

As you write about your results, refer to the graphs and tables so that they clarify the results for the reader. Comment on them as necessary, and refer specifically to key parts of the figures as needed. For example, "We digested the plasmid with restriction enzymes (Figure 1)" is not nearly as informative as "We digested the plasmid with restriction enzymes (Figure 1) and found that it had only a single *Eco*RI site (lane 1 in Figure 1)." Integrate your graphs and tables into your text (rather than placing them at the end of the paper), and put them close to the point where they're referenced for the first time. The sample in Figure 1 shows how this should look; Figure 2 shows how it should not look.

In Results, you should not only report your raw data but also *analyze* it so that the reader knows what it means. (In fact, in many cases you don't need to give all your raw data: if you include a graph which shows all your data points, don't also make a table!). In Figure 2, the writer just throws the data out there, and the reader has to do all the work. Contrast this with Figure 1, where the writer comments on the data in detail and analyzes it carefully, making it easy for the reader to see its significance. Don't forget that statistical analysis can be an important part of your results: use standard deviations, T-tests or other appropriate

Differential rates of cookie disappearance. Fifty chocolate-chip cookies (see Materials and Methods for recipe details) were placed in each of two identical jars. Jar 1 was placed in the Science Division office, which is normally locked at night, while Jar 2 was left in a public hallway. Numbers of cookies remaining were measured daily for 10 days; the results are shown in Figure 1. Rates of disappearance were essentially linear, with a much steeper slope for Jar 2 (triangles and dashed line in Figure 1) than for Jar 1 (squares and solid line in Figure 1). No error bars are shown because this preliminary experiment was done only once. Rates of disappearance were calculated from the slopes (see Table 1), and Jar 2 had a rate of disappearance nearly twice that of Jar 1.

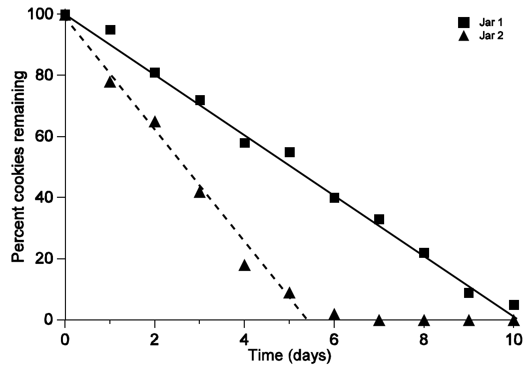

Fig. 1. Reduction in cookie numbers over a 10-day period. Number of cookies remaining was measured for two jars (Jar 1, squares and solid line; Jar 2, triangles and dashed line) as a percentage of cookies present on Day 0.

Table 1. Calculated Rates of Cookie Disappearance

Sample	Rate (cookies/day)[a]
Jar 1	5.00
Jar 2	9.09

[a]Rates were calculated by the least-squares method.

Figure 1. An example of part of the Results section of a well-written lab report. Notice the clear, properly formatted graph and table. The text briefly explains the experiment, describes the results and refers specifically to the figure and table.

forms of analysis to demonstrate the significance of your results (see the section on statistical analysis, page 45, and your *Handbook of Biological Investigation* for more help with this).

When we did the cookie experiment, we saw that the cookies disappeared faster from the second jar (Figure 1).

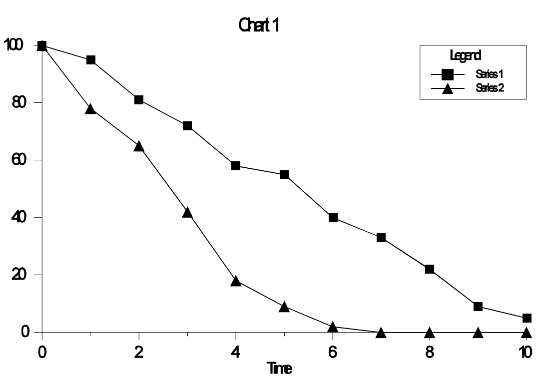

Figure 2. A bad example. This sample uses same data as in Figure 1, but notice the enormous difference in how it is presented. The style is not scientific, the chart is constructed carelessly, the text does not inform the reader about the experiment or discuss the results in detail, and the writer fails to analyze the data for the reader.

Students sometimes don't think there is much to say about their data, but there usually is plenty to say, and plenty of analysis that can be done. If you don't think you have anything to say, maybe you just haven't looked carefully enough at your data! Again, contrast the student who has "made the most of the data" in Figure 1 with the writer of Figure 2, who hasn't taken the time to see what the data are saying.

Your Results section should "tell the story" of your work in a clear, readable style. It should be able to stand alone: if a reader skips Materials and Methods and jumps straight into Results (which is often the case with a real paper, unless the reader needs to know about a specific technique), s/he should clearly understand your results and how you got them. This means you'll need to tell a little about why and how you did each experiment. Avoid, however, the temptation to include your conclusions here; analyze your results and give as much interpretation as is necessary to understand the next experiment, but save your conclusions for the discussion section. For example, "The caffeine-treated mouse completed the maze 44 seconds faster than the control mouse" is appropriate for Results, and so is "We noticed in the first two experiments that brown mice completed the maze an average of 12% faster than white mice, leading us to test specifically whether maze running ability correlates with the color of the mice." However, "These results suggest that caffeine improves maze-running ability in mice" is a general conclusion that belongs in Discussion.

Illustrations

Every illustration in a scientific paper is either a figure (graph, drawing, photograph, etc.) or a table (table of numerical data). Don't refer to an illustration as "Chart 1," "Graph 1," etc. Number your figures sequentially (Fig. 1, Fig. 2…) in the order that you discuss them, and number your tables separately (Table 1, Table 2…).

Figures should have a legend (caption) at the bottom which describes very briefly what's going on and identifies symbols. They should not have titles. Graphs and diagrams should be computer-drawn; however, it is certainly appropriate to add hand-drawn best-fit lines if your graphing program (Excel is the major graphing tool available to you on campus) doesn't give an appropriate line. Be sure your graph presents your data appropriately! If you're trying to show a relationship between two variables, for example, plotting points and adding a best-fit line might be the best way to present the data. Other kinds of data might be presented more clearly in the form of a bar graph. If you are not showing a specific relationship or trend, consider a table, particularly when the number of data points is fairly small. When appropriate, include error bars, standard deviations or other statistical measures.

Be aware that the default settings of Excel are not necessarily the ones you want—if you let it, it will often spit out connect-the-dots graphs with colors and symbols that may not print well. Almost every aspect of an Excel graph can be configured, if you take the time to learn how! Be sure your graph is clear and shows what you want it to. Also pay attention to the scale—if you have two graphs showing related data but they have very different scales, the reader can't easily compare them. So, make the scales the same or put both data sets on one graph. Additional graphing tips are found in the Excel section (page 49).

A **table** should have a title but not a caption; any important details can be given in a footnote at the bottom of the table. Think carefully about your data and decide whether a graph or a table is the most appropriate format for presenting it. The goal is for the reader to grasp the meaning of the data clearly and quickly.

Discussion

While the Discussion is less important than the Results section (because it's not where the actual results are communicated), it is usually more fun to read, because it explains what the research *means*. In this section, you discuss the major findings, summarizing results but not repeating the Results section. Here is also where you draw conclusions, presenting your evidence for each conclusion. Tell whether you met the objectives you set out in the Introduction, and why.

You can also explain problems with the experiments, discuss possible sources of error, and comment on possible future experiments. It is appropriate to use reference material (properly cited) in the Discussion section, especially to compare your results to those of others. Both past tense (when you're talking about your results) and present tense (when you're making a more general statement) can be used in Discussion. Below is a paragraph from the discussion section of the cookie-jar report; notice how it very briefly reminds the reader of the results and includes conclusions, a comparison with a previous study and *specific* ways that the experiment might be improved in a future study.

The difference between the rates of disappearance of cookies in Jar 1 (office) and Jar 2 (hallway) is striking. Cookies disappeared nearly twice as fast (9.1 vs. 5.0 cookies/day; see Figure 1 and Table 1, above) from Jar 2. It is important to note, however, that this experiment was done only once; hence, these data cannot be regarded as statistically significant. Based on this single experiment, we have tentatively hypothesized that the increased rate of disappearance results from the higher level of pedestrian traffic, particularly at night, in the hallway. This hypothesis is supported by data recently published by Smith and Jones (1978), demonstrating that at least twice as many people have access to the hallway in a 24-hour period. However, we cannot exclude the possibility that there may have been differences in quality that made the cookies in Jar 2 more desirable. This experiment should be repeated , and we should ensure that the cookies in both jars come from a single batch or are randomly distributed.

Every conclusion that you draw in the Discussion section must be carefully supported with evidence drawn from the data you presented in Results. Don't assume that the reader understands how you came up with your conclusions: refer back to specific results and build your case, much the way a lawyer builds a case for a client's guilt or innocence in a closing argument. It's OK to include some speculation about possible explanations for which you don't yet have evidence (usually in the context of suggesting future experiments), but *any* actual conclusions which you make about your data must be properly supported.

It is very common for undergraduates to think that their experiments "failed," or "didn't work right." Guess what? *Every* experiment "works"—that is, it produces a result. However, it is your job to <u>interpret</u> that result. In some cases, the result may support your hypothesis. Other results may contradict your hypothesis; if that happens, you may have evidence that your observations were due to a problem with the experimental design (so that your experiment didn't properly test the hypothesis) or to a *specific* error in carrying out the experiment. Or, it may simply be that your hypothesis and expectations were wrong, and your results are pointing out to you that you must consider alternative explanations.

Always think about your data first in terms of biological explanations. In the discussion, tell the reader the *why* of your experiments: what actually happened in the cell, organism, DNA, etc. that explains why you observed what you did. If necessary, discuss problems with the experiment itself, but do <u>not</u> use the wimpy generalization "there must have been experimental error" (or worse, "my results are due to human error"). If you think you made an error, we need to know what *specific* error would have accounted for the results you got. Discussing the data thoroughly means you spending serious time thinking about it!

Don't forget to discuss your controls! Controls validate your data; if they don't turn out as expected, then something is very wrong with the design or execution of your experiment. The discussion is a good place to talk about the controls you used, why they were important, and how the control results affected your interpretation of your data.

References and citations: giving credit where credit is due

Citations and References

The sources of the information you use in your report must *always* be properly credited. In your introduction, you might refer to a specific previous study whose results are related to the work you are doing; obviously, you must identify the source of that study. It is perhaps less obvious that *even well-known facts* (such as, "The first step in glycolysis is carried out by the enzyme glucokinase") should be properly credited in your paper. Someone else did this work, and your identification of the source (which could be a primary article from the scientific literature or just a textbook) gives that person appropriate credit. ***Failing to credit the sources of your information is plagiarism!***

When you use source material in your text, you use a **citation** to identify it. In scientific writing, direct quotations are not used; all source material is paraphrased. Complete information on each source is then given in a **reference list**. Unless your instructor specifies another style, North Central biology courses use the author-date format for citations with complete references at the end of the report in alphabetical order. The correct format is detailed in the section Finding and Citing Sources, starting on page 39. Please read this section carefully and adhere to it precisely, just as you would if you were writing a manuscript for a real journal.

Your Sources

Any sources you use should be scientific sources. These might be **primary articles**, which are papers written by scientists reporting their own research and will show actual data in the form of photographs, graphs, tables, etc. Primary articles are found in journals like *Genetics*, *Journal of Bacteriology*, *Cell*, *Science*, or *Nature*. Or, you might use scientific secondary sources, such as **review articles** (in which scientists summarize recent work in a particular area for other scientists); these usually appear in the same scientific journals as the primary articles, or in journals devoted specifically to reviews (*Annual Reviews of Genetics*, for example). Other scientific sources such as textbooks or general-interest publications written for a *scientific* audience (*Scientific American*, *Natural History*) are also acceptable.

Do *not* use any newspapers, popular press publications (*Time*, *Newsweek*, etc.), encyclopedias, etc. to establish scientific facts. The only time you might want to use a source of this kind would be discuss a popularly held view about a scientific topic. **Web references are absolutely not acceptable unless you are specifically directed otherwise by your instructor**. *Anyone* can post *anything* to the Web, and there is no guarantee of its accuracy—or that it will even still be there when your paper is completed. If the material you find on the Web is accurate, you will also be able to find it in a published source.

In order to qualify as a source, you need to have read the actual paper, not just the abstract or even a "full-text" on-line version (a scientific paper is nothing without its figures: no data for you to judge the quality of!). The library has lots of databases, and different ones have different kinds of articles in different formats…it can be tough to decide when you have or haven't seen the actual paper. In order to make it clear and simple, our standard is that you must obtain either (i) a copy of the actual paper in the printed journal (from our library, another library or interlibrary loan), (ii) a copy of the actual paper from microfilm, or (iii) an electronic version of the actual paper in PDF format.

This is not difficult to do, but you'll have to plan ahead. You may be able to find the actual journal or microfilm in our library, or you may be able to find a PDF version on-line (the library has on-line subscriptions to a number of journals, and many others are now making year-old issues available on-line for free). Or, you can go to one of the many excellent libraries nearby: U of C, Northwestern, UIC and Loyola, for example. Or, you can ask the library to order the article for you, for a small fee (but be warned: this can take a couple of weeks!!). If you're desperate, sometimes you can buy a single article on-line without subscribing to the journal, but the prices for this are seriously inflated. ***Don't wait until the last minute to start looking, or you'll find yourself sadly lacking in the necessary references!!*** More information on where and how to look for references is found in the Finding and Citing References section (page 35).

Scientific writing style

You're not communicating effectively if the *style* of the paper is not as good as its *content*—in fact, an effective writing style can often greatly improve your reader's opinion of your results, while sloppy writing can mar great results by distracting the reader from the paper's content. Your paper should be polished and professional—so much so that you would be willing to submit it for publication in a journal or for a scientific meeting. It should be computer-printed. It should be double-spaced—except for the abstract, which is single-spaced. Before turning it in, go back through your syllabus and the checklist on page 27 to be sure your report meets all of your instructor's expectations. Do not turn in a paper that you know does not meet the minimum requirements—do whatever it takes to bring it up to standards.

Your tone should be scientific. This does not mean being stuffy and boring and using big words. Good scientific writing is clear, direct and readable. But it does mean writing precisely, using appropriate scientific terminology and maintaining a certain formal tone. Again, the best way to learn how to write in scientific style is to read good papers written by others, so spend some time at the library looking at articles in good scientific journals. The example below might help give you an idea of what this style is like:

too informal:	Mitochondria are little energy factories for cells. We made a cell's environment less sour and the cell couldn't make its energy as well.
too wordy:	Intensely energy-rich molecules are thermodynamically manipulated by the cellular mitochondrial machinery, utilizing energy-generation mechanisms such as oxidative phosphorylation, to the energetic benefit of the cell. When the hydrogen ion concentration was decreased by experimental manipulation by a factor of 100-fold, the resulting pH increase produced a cellular effect in which the concentration of cellular energy currency decreased disproportionately.
not clear:	In our experiment, pH had an effect on mitochondria.
good style:	Mitochondria use gradients of hydrogen ions (protons) in producing ATP, so a change in pH (H^+ concentration) might be expected to affect ATP production. When the growth medium pH was raised from 7 to 9, ATP production quickly dropped to 0.01% of normal.

Use standard symbols and abbreviations (mg, mM, °C, µl, etc.). If you use an abbreviation that would not be immediately recognized by any reader with a science background, spell it out the first time. Remember that genus and species names of organisms are always italicized (*Escherichia coli*, *Homo sapiens*); the genus name is capitalized but the species name is not. Do not add superscripts, Greek letters, figure captions or other details by hand: if you don't know how to make your computer add these details, now is the time to learn. Don't make last-minute corrections by hand, either—change the file and re-print the paper. Small details contribute significantly to the overall professionalism of your paper.

<u>Never turn in a first draft</u>, and never turn in even a final draft that is "hot off the press" and hasn't at least been read through one last time to check for typos. If you have trouble organizing your writing or maintaining a smooth flow of ideas, write a detailed outline first. When you write a draft, put it aside for a little while and then attack it viciously! Even an excellent writer's first draft is likely to need *significant* revision to make it as clear, precise, persuasive and professional as possible. This means not only proofreading for typos but carefully analyzing each paragraph, each sentence to see whether it has the effect you intended or if it could be said better.

Spell-check your paper, but remember that this will *not* catch punctuation, grammar and style errors (it doesn't know whether you meant "affect" or "effect," "due" or "do"). There is no substitute for carefully proofreading your paper. Also, spell checkers often don't know scientific terms, so don't blindly accept suggestions (for example, Microsoft Word thinks that "absorbance" should be replaced by "absorbency"). Grammar checkers are of almost no use unless you want to write on a sixth-grade level, so don't waste your time. Buy a good dictionary and a good guide to English style and use both frequently. It is often helpful to have another student read your paper, both for errors and to see if you got your point across well.

Some people believe that there should be no "passive voice" in a scientific paper. Indeed, <u>excessive</u> passive voice can make a paper seem awkward and hard to understand: "The river was waded into by the investigator, and a water sample was collected by the investigator and handed to the investigator's assistant." However, too much active voice can get repetitive and sometimes doesn't carry the proper scientific tone: "*I* took the sample…*I* analyzed the sample…*I* found…*I* concluded…). If your style is clear and direct, don't be overly concerned about voice. For example, "These experiments were done in a hood, and I took two samples at each time point" combines both active and passive voice without being wordy or unclear.

Plagiarism

Standards for academic honesty and definitions of plagiarism are discussed in detail elsewhere in this handbook. However, it might be useful here to briefly list some specific examples of *unacceptable* use of others' work as they pertain specifically to lab reports. Please remember that any academic dishonesty is subject to sanctions which could be a severe as failing the course or being dismissed from the College.

- Using a graph or other figure prepared by another student in your lab report
- Working with your partner to produce one graph or other figure which you then both use in your lab reports
- Asking your partner or another student to let you read his or her lab report and then using what he or she has written as the basis for your own report
- Working together with a partner on the actual writing of the lab report, so that two partners turn in identical or extremely similar reports (collaborating with your partner on understanding the experiment and analyzing the data is perfectly acceptable—in fact, encouraged—but each partner must do his or her own writing unless an instructore has specified that two partners may turn in a single lab report)
- Failing to give credit (a properly formatted citation and reference) for *any* non-original facts or ideas used in the report
- Using data from another lab group or any data that you did not personally obtain, unless you have specific permission from your instructor to do so
- Making up data, adjusting data to "come out right," leaving out pertinent data that doesn't fit your hypothesis or any other unethical manipulation of data

Formal Report Checklist

Title/Abstract:

- ☐ Specific title describing the topic and/or main conclusion
- ☐ All contributors listed as authors below the title; writer identified with an asterisk
- ☐ Abstract single-spaced; briefly summarizes entire paper, including results & conclusions

Introduction:

- ☐ Introduction provides sufficient background for reader to understand the experiments
- ☐ Introduction shows why the experiments are important and significant
- ☐ Introduction includes your hypothesis and the rationale on which it is based
- ☐ All non-original facts and ideas identified with citations and references in proper format

Materials and Methods:

- ☐ Materials and Methods gives enough detail that the experiment could be repeated
- ☐ Materials and Methods is a concise, compact description in paragraph form, using full sentences (not a list of materials or a set of directions)
- ☐ Source(s) for procedures are properly cited

Results:

- ☐ Results section begins with a sentence or two of introduction
- ☐ Results "tells the story" of the experiment and could stand alone
- ☐ Results section describes the results in words, not just figures
- ☐ Results section refers to and comments on graphs, tables and other figures (by number)
- ☐ Results section includes analysis of the data, including appropriate statistical analysis
- ☐ Results section is written in past tense

Discussion:

- ☐ Discussion briefly recaps results
- ☐ Discussion focuses on biological explanations for the results: *why* were these results obtained? What was going on in the cell or organism that led to these results?
- ☐ Any *specific* problems are discussed, avoiding generalizations like "experimental error."
- ☐ Controls are discussed carefully
- ☐ Your hypothesis (from the Introduction) is evaluated
- ☐ Possible future directions or improvements to the experiments are discussed

General:

- ☐ Graphs, tables and illustrations are clear, formatted properly and integrated into text
- ☐ Figures are numbered and have descriptive captions but no titles; tables are numbered separately and have titles but no captions
- ☐ Sources for <u>all</u> non-original material are properly identified by citations in the text as well as full references at the end of the report
- ☐ Style is clear, concise, formal and scientific throughout
- ☐ Standard symbols, abbreviations, subscripts, superscripts, etc. have been used
- ☐ Report has been through at least two complete drafts with careful reading, editing and re-writing; final draft is carefully proofread and free from writing errors.

we observed that the coconut macaroons disappeared more slowly. Very similar results were obtained in each of three trials. Average data for the three trials, reported as percentage of cookies remaining are shown in Figure 1.

We then determined the rate of disappearance for each trial of each kind of cookie using best-fit linear trendlines. The average rates are shown in Table 1. Note that for the chocolate-chip cookies, we observed that the rate of disappearance slowed after about seven hours in each trial; therefore, we calculated rate using only the data for the first seven hours in order to measure a linear rate of disappearance. We used Student's *t*-test to compare the rates and found that the rate of disappearance of the chocolate-chip cookies was significantly higher than the rate for the coconut macaroons ($p < 0.001$).

Table 1. Rates of cookie disappearance

cookie type	rate of disappearance[a]
chocolate chip	10.5 ± 0.8 %
coconut macaroon	3.4 ± 0.2 %

[a]average of three trials; reported as percentage of cookies disappearing per hour ± one standard deviation.

Discussion

This experiment was designed to test the hypothesis that cookie disappearance rates would be affected by the type of cookie used. Specifically, we compared the rate of disappearance of chocolate chip cookies to that of coconut macaroons. We found that chocolate chip cookies disappeared nearly three times faster, a statistically significant difference which supports our hypothesis.

This difference in disappearance rates was consistent across three trials, and the relatively small standard deviations in the data We also observed a consistent slowdown in disappearance of the chocolate-chip cookies after seven hours. This phenomenon could be due to reduced foot traffic later in the day or could be due to the limited number of cookies remaining in the jar at this point. Increasing the duration of the experiment so that the number of macaroons remaining also approaches zero could provide further information.

Previous research (House, 1999) showed that chocolate chip cookies are among the yummiest available, scoring on average 10 Yums (Ym) higher than coconut macaroons. Taken together with the data reported here, this suggests that their high rate of disappearance may be due to higher appeal to passing *Homo sapiens*. Future experiments will test this hypothesis.

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