A Student's Guide to Writing in the Life Sciences

2nd Edition

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A collaborative work

A team of innovators, contributors, and funders has made this guide possible. Professor Robert Lue initiated the project to improve the teaching of writing in the Life Sciences at Harvard University and has sustained the project's vision over several years. Produced through collaborative efforts of the Department of Molecular and Cellular Biology and the Harvard Writing Project, the guide could not have been written and published without the combined generous support of a Gordon Gray Faculty Grant for Writing Pedagogy and a Howard Hughes Medical Institute Grant, both awarded to Professor Lue.

Table of Contents

Chapter I
Writing in the Life Sciences

Chapter II
Specific Types of Writing in the Life Sciences

Chapter III
Writing Strategies and Feedback

Chapter IV
Finding and Using References

Chapter V
Related Skills

Appendix
Additional Resources

Chapter 1

Writing in the Life Sciences

My aim is to put down on paper what I see and what I feel in the best and simplest way.
Ernest Hemingway

Introduction

Writing well is one of the most important skills you will tackle in college. Writing is not just an important form of communication, but it also helps you develop, organize, and solidify your ideas and thoughts. At the same time, writing is among the most difficult skills to learn and teach. This difficulty is especially pronounced in science classes, where the focus is usually on science content, not on writing. While there are plenty of writing assignments in science classes, there is typically little attention paid to the writing process itself. This situation is unfortunate, as writing is central to science. Writing serves as a way to communicate scientific ideas and findings to other scientists as well as to the public. Importantly, writing is also part of the scientific process. The keeping of laboratory notebook, the writing of a research proposal, and the telling of a story in the form of a research paper are all integral parts of scientific thinking. The education of scientists, therefore, needs to consist not only of learning content and methods, but also of mastering both the general elements of writing and the specific aspects unique to scientific writing.

A new initiative, Writing in the Life Sciences, began at Harvard University in response to the recognition of the importance of writing in science and the lack of a consistent, clear, articulated writing curriculum for undergraduate science students. While much thought and energy have been put into the undergraduate science curriculum, a parallel, complementary look at the writing curriculum in the sciences has not been undertaken. Many undergraduate science classes do have writing assignments, but there is little focus on the connection between the writing assignments in the various courses, the quality and consistency of the feedback on the writing assignments, and the importance of writing to the scientific process.

One of our goals, therefore, is to articulate and put into place a coherent writing curriculum for undergraduate science students. We envision a two-way conversation, with writing that communicates scientific thought, and science that comes to life through writing. Just as you progress through a series of classes, each one building on the scientific content of a previous class, you will also move through a writing curriculum, with assignments that build on skills learned in previous classes. That is, the writing curriculum will be integrated into the science curriculum. We hope that this dual approach will make for better writers and for better scientists.

In the fall of 2004, we had several preliminary meetings to understand what kind of writing curriculum is already in place in undergraduate biology classes, where needs are perceived, and what models can be used from the experiences of other departments at Harvard. These meetings benefited greatly from contributions of faculty, staff, and preceptors from the Biology Department and Expository Writing Program. We learned that the core introductory biology (50-level) classes do have a variety of thoughtful writing assignments. In addition, we learned that the Expository Writing Program has worked with a number of departments, most recently Psychology, East Asian Studies, Economics, and Government 10, to create writing guides specific for their concentrators.

As a first step to foster a stronger culture of writing in the sciences, we put together this guide to undergraduate writing in the sciences. This guide addresses elements of writing in general and writing in the sciences in particular, provides instructions on and examples of different types of writing, discusses how writing assignments are evaluated, and points out writing resources available in the Harvard community. Our hope is that this guide will serve as a useful resource for students, teaching fellows, and faculty.

We see this project as an ongoing one to think about and address issues of writing in the undergraduate science curriculum. For example, over the next several years we will begin to focus more deliberately on the sequence of writing assignments that you encounter as you move through the biology curriculum. Our eventual goal will be a thoughtful, articulated, evolving writing curriculum that serves students in the sciences, as well as one that provides a model for undergraduate writing in the sciences in general.

Links to Expository Writing

Expository Writing (Expos) is Harvard's introductory course in college-level writing, required of all first-year students. If you are using this guide, Expos is probably well behind you. However, it is not time to forget about the lessons you learned in Expos, as much of what you worked on and learned is directly relevant to writing in the sciences. Some of these are obvious; clarity, organization, elements of grammar, and use of sources clearly apply to any kind of writing. But the connections to Expos actually run deeper than these standard elements of good writing.

Two elements of writing that are particularly emphasized in Expos are argument and evidence. The Expos philosophy holds that to think effectively, you have to write well; thus, in your Expos class you worked on strategies of argument. By writing drafts and revisions, you discovered your ideas and practiced ways to convince your readers that those ideas were valid: in each paper you focused on articulating an idea that readers could reasonably disagree with; you established why readers should care about that idea; you substantiated your argument with evidence that you carefully analyzed. You learned as well the importance of anticipating objections that your readers could make to your findings when there was counter-evidence to consider.

Argument and evidence not only are well at home in scientific writing, they are in fact central to it. For example, a research paper or research proposal builds a story or argument by carefully putting together different pieces of evidence. The evidence, in the case of science, often comes from scientific papers or from one's own observations or experiments. However, as in other forms of writing, scientific writing uses these pieces of evidence to craft a well-substantiated argument designed to convince the reader of a particular point-of-view. While there are particular style conventions that are unique to science writing, the importance of argument and evidence should not be forgotten as you embark on your own science writing assignments.

Using this Guide: A Guide to the Guide

So why focus on writing in the sciences? In many ways, writing in the sciences is no different from writing in other fields. Both require a clear argument or thesis, careful use of evidence and sources, organization, and attention to grammar and wording. Both also require a good deal of thought, as good writing often reflects a clear understanding of the subject. In fact, the process of writing itself can often help to formulate and solidify ideas.

However, there are also aspects of writing in the sciences that are particular to science. Writing in the sciences follows certain conventions, styles, and formats. These are considered in Chapter II, where we describe in some detail the major forms of writing you are likely to encounter in the sciences, including short answers and essays typical of science examinations, the laboratory notebook, research papers, research proposals, reviews, and writing for the general public. Chapter III focuses on a key aspect of good writing, namely rewriting. Rewriting is often informed by feedback, so we have also included here a section on how writing is evaluated. In addition, we have included in this chapter a list of the common writing mistakes that we encounter in reading student assignments. Alerting you to these is the first step in avoiding them. Chapter IV deals with sources and references, giving tips on how to find useful references, as well as instructions on how and when to cite your sources. Finally, in Chapter V, we have included a discussion of two related topics: how to read a scientific paper and how to prepare an oral presentation.

As you read through this guide, keep in mind that while there are many types of writing assignments, each of which follows a different format and set of rules, there are also common threads that run through these various types of writing, as well as between writing in the sciences and writing in general.

Chapter II

Specific Types of Writing in the Sciences

I write entirely to find out what I'm thinking,
what I'm looking at, what I see and what it means.
What I want and what I fear.

Joan Didion

Writing in the sciences takes many forms. Here we consider specific types of writing that you are likely to encounter in your undergraduate science classes. If you go on to become a scientist, be it in academics or industry, or a physician, you will constantly revisit these various forms of writing. For each, we provide an overview as well as detailed instructions. These instructions are meant to provide a general guide; you should follow the specific instructions you receive in assignments that you have for class.

Short Answers

We begin this section of the Guide with a form of writing that you will encounter many times as a student, but less frequently, if at all, as a practicing scientist: the short answer or essay form. This type of writing comes up on many of the examinations of the introductory sequence of biology classes at Harvard, so it is worth at least a brief consideration here. In some ways, this is the simplest form of writing; you are asked a direct question and given a limited amount of time and space to answer it. The questions are not usually open-ended, but instead are direct and straightforward. At the same time, writing short answers can present a special challenge. Sometimes, it is harder to write a brief answer than to write at greater length. In a short answer or essay, words must be chosen carefully and consideration must be given to what to include and what not to include. This takes some practice and thought.

When answering a short answer question on an examination, one of the most important points is to make sure you are answering the question being asked, not the question you hoped would be asked. For example, if the question asks to compare and contrast elements of mitosis and meiosis, the answer should do just that, compare and contrast. Consider this example of a student answer:

> Mitosis and meiosis are both forms of cell division. While mitosis produces two identical daughter cells from a single parent cell, meiosis produces four haploid cells from a single diploid cell. The different products of the two forms of cell division result from a difference in the mechanics of the two processes. In mitosis, a single round of DNA synthesis is followed by a single round of chromosome segregation. By contrast, in meiosis, there is a single round of DNA synthesis followed by two rounds of chromosome segregation. It is also important to note that the products of mitosis are genetically identical to each other and to the parent cell, while the products of meiosis are genetically distinct as a result of chromosome segregation and crossing-over, two processes that lead to genetic diversity.

This answer nicely compares and contrasts the two processes; it puts the two side-by-side and discusses similarities and differences in a thoughtful manner. Now consider this response:

> Mitosis is a form of cell division that produces two daughter cells from a single parent cell. It consists of the following steps: Interphase, Prophase, Metaphase, Anaphase, Telophase, and Cytokinesis. The resulting cells are genetically identical to the parent cell. An example of mitosis is the cell division that occurs as a fertilized egg divides to produce all of the cells in the body. Meiosis is a form of cell division in which four cells are produced from a single parent cell. There are two rounds of cell division and only a single round of DNA synthesis, so a single diploid cell produces four haploid cells. Genetic diversity is produced by crossing-over.

Notice that this answer is accurate and correctly describes the two processes, but leaves the comparing and contrasting to the reader. As a result, it does not really answer the question being asked. The student has conveyed information, but has not processed it or even answered the question. So, in short, if the question asks for a list, provide a list; if it asks to discuss, discuss; if it asks to compare and contrast, be sure to consider similarities and differences.

In addition to answering the question, be sure to present all of the relevant facts. Normally, an instructor is looking for a set of key terms or ideas and it is up to you to convey all of them. Sometimes it is useful to first jot down key thoughts or terms before you begin to answer the question, as a kind of checklist to yourself to be sure you are including all of the major points.

While your goal is to present all of the relevant facts, this does not mean to present everything you know about a subject. Stick to the relevant facts; do not include superfluous or unnecessary information. If what you write is not relevant to the question, you will not receive extra credit, and it if is irrelevant and incorrect, you may lose points. Answering questions on an examination is not just an exercise in conveying information, but also a chance to demonstrate that you are able to read and answer questions.

Laboratory Notebooks

Many of your science classes have a laboratory component. Laboratory exercises are designed to give you hands-on experience with techniques and to illustrate some of the concepts that are introduced in lecture. This is also the place to learn to ask questions, develop a hypothesis, design or carry out an experiment to test the hypothesis, collect and analyze data, and present your work.

Central to the process of doing science is the keeping of an organized and thorough laboratory notebook. In order to become a good scientist, you must learn how to keep an accurate and current record of all experimental procedures, observations, and results. Your notebook is your own personal reference when writing a formal report or article on the experiments you have performed.

When you keep a laboratory notebook, you also leave behind a legacy once you leave the laboratory. Anybody who follows in your experimental footsteps should be able to go to your notebook and, without additional references, repeat every single experiment reported there. In fact, when you work in a research laboratory, your notebooks are the property of that laboratory and you are legally responsible for their contents.

The keeping of a laboratory notebook is a very important form of scientific writing and in some ways can be thought of as the cornerstone of all other types of writing. There are various forms of writing that you will learn about in your biology courses at Harvard, but all of them build on the critical skills of effective communication, organization, and data interpretation that are first practiced in the laboratory notebook.

Laboratory notebooks often follow a particular format, which is described on the following pages:

Table of Contents. Every experiment in your notebook must be documented in the table of contents. The first page of a notebook is typically reserved for the table of contents, but some, including the ones recommended above, have a table of contents page already included. In your table of contents, record the following information:

- the number and title of each experiment;
- the date when the experiment was started;
- the page number where documentation for that experiment begins.

Date. At the top of the first page, record the date the experiment was performed. Each subsequent page should also be dated. On the first page for that experiment, write out the full date (month, day, year). Subsequent new pages used with that same date can be dated at the top using an abbreviation (X/X/XX). In either case, place the date close to where the page number is located. If an experiment is carried out over several days, it must be clear which steps in the procedure were carried out on each date. You may put a range of dates at the top of each page, and then indicate within the write-up (in Notes and Changes to Procedure section) what was done when.

Number and Title of Experiment. The number and title of the experiment should be written at the top of the first page of an experimental write-up. The title should be descriptive, but not too wordy. Examples of good titles include "Observing Mitosis and Meiosis" and "Complementation and Meiotic Mapping in *Saccharomyces cerevisiae*."

References. Reference any source you used to prepare for the laboratory. You will definitely need to reference the laboratory manual, and you may also want to reference the textbook or any other source of background information you used. Here are two examples:

> Biological Sciences 50 Genetics and Genomics Section Manual, Fall 2004, pp. 12-16.
>
> Hartl, D. and Jones, E. Essential Genetics: A Genomics Perspective. 3rd ed. Sudbury: Jones and Bartlett, 2002.

Collaborators. Acknowledge the contribution of your laboratory partners by including their names in this section.

Purpose. In this section, you are explaining why you are performing the experiment and how you will do it. Not only is this section useful to others who may want to replicate your work, but it can also be tremendously helpful to researchers when they are reviewing their own work. In one paragraph, succinctly convey the goal of the experiment or the experimental question, why the experiment is being performed, how the experiment will be carried out (methods or techniques used), and any relevant background information. If relevant, also briefly discuss possible outcomes. This section should be no more than a half of a page.

Materials. List equipment and supplies, reagents and chemicals (even water), names of organisms used and their strains or genotypes. Also include the manufacturer of a reagent or supply if a particular item can only be obtained from that company—e.g., Ready-To-Go PCR Beads (Biorad).

Planned Procedure. In this section, present the procedure that is outlined in the laboratory manual in your own words. Do not copy blindly. List in step format. The steps can be brief, but must be descriptive enough for someone to be able to follow your directions. Also include helpful notes (wear gloves, keep tube on ice, perform this step in the hood).

Pre-laboratory Exercises. Some laboratories will have pre-lab questions or exercises (found in the laboratory manual); present your work here.

Notes and Changes to Procedure. This section is completed during the laboratory period. Note any deviations from your planned procedure. Also make notes and observations pertaining to the experiment and anything that you think is important to note about what happened or what you saw. Remember, someone should be able to read your notebook and do exactly what you did, not just what was listed in the laboratory manual. Be sure to make note of mishaps or anything that you think may affect your results. Always make clear the part in the procedure to which you are referring.

Here are some examples:

- Step 1 was already completed by the teaching staff before the laboratory period.
- When loading the molecular weight markers in the gel, 20 ul was loaded, not 10 ul as written in step 4.
- This group's yeast plates were contaminated with bacteria so another set was used (supplied by J. Watson and F. Crick).
- Step 5: agarose gel was run for 45 minutes at 100 volts.
- For step 6, 53 colonies were identified and streaked to the master plate.

Do not forget to include what happens to your experiment in your absence:

- The TF incubated the plates at 30°C and then transferred them to 4°C after 24 hours.

Results. This section should include any raw data that you produce during the laboratory period, such as tables of yeast spore genotypes, charts of color changes of samples, photographs, drawings of observations. Anything presented in the results section should be labeled with a descriptive title and measurements should always be labeled with appropriate units. Do not forget to make a copy of any photograph or drawing to put on the duplicate page.

Data Analysis. This section will include any calculations, manipulation of the data, or conclusions that you make after the laboratory period. Items that might be found in this section include a table of molecular weight vs. distance migrated and accompanying graph, calculations (Chi square test) and determination of linkage, or identification of unknown strains based on information presented in the results section. Again, do not forget to include titles, all appropriate graph labels, and units of measurement.

Discussion. In this last section, evaluate and discuss the success of the experiment. Write as if your audience is someone who wants to repeat your experiment, or someone who wants to move forward from your experiment (this could be you, at a later date). What does that person need to know? Include interpretation of your results—how you came to the conclusions presented in the previous section and whether or not your conclusions agree with any of the outcomes discussed in the Purpose section. What did you learn from the experiment? If the experimental outcome contradicted expected results or produced surprising results, suggest possible reasons or address possible sources of human or equipment error. Keep in mind that just because an experiment does not give expected results does not mean that the procedure or the execution of it was flawed. Unexpected results can be real and can lead to alteration of current models and ways of thinking (but only if someone else can read your notebook and repeat your experiment). Also in this section, address any questions posed in the laboratory manual.

Signature. When you complete each experimental write-up, sign and date your work. Put the date that you did the calculations and finished the work, not the date you did the experiment (this should already be documented in your notebook). Cross out any remaining blank space on the last page with a diagonal line.

Other Notes about your lab notebook:

- Write legibly.
- Laboratory notebooks are bound books, with numbered pages that cannot be removed from the book (i.e., a 3-ring binder with loose leaf paper is not acceptable).
- Inside the front cover and on the table of contents page, provide descriptive and identifying information: your name, e-mail address, university, course number and title, laboratory room number, and teaching fellow.
- Do not remove any pages from your laboratory notebook. Original, consecutively numbered pages must always remain.
- Do not skip pages. If a page is accidentally skipped, draw a diagonal line through it.
- Because laboratory notebooks often have duplicate pages, write only on the front side of each page.
- Write in black or blue ink. Do not use pencil.
- Do not make erasures or heavy scribble outs, or use white-out. If you need to change something, draw a single line through it and write your correction on the next line. Nothing in your notebook should be obscured.
- Update the table of contents each time you use your notebook.
- Start the documentation of each new experiment on a fresh page.
- During the laboratory period, carry your notebook with you wherever you go and enter data or observations as you have them. Do not write information on scraps of paper and enter it into your notebook later.
- Photographs, computer printouts, and other data generated by something other than your pen should be taped into the notebook. A photocopy can be taped to the duplicate page.
- When an experimental write-up is completed, sign and date it. Cross out any remaining space on the last page with a single diagonal line.
- Use continuation notes when an experiment requires more than one page. At the bottom of each page, write "continued on page ___"; at the top of each page, write "continued from page___". This is particularly necessary when a single experiment is not documented on consecutive pages (which often happens when a new experiment is started before an ongoing one is finished).

Research Papers

A research paper is the currency, the mainstay of scientific information. This is the place where new results and ideas are communicated to other scientists. Most of the facts you learn in a science lecture or textbook are actually interpretations of data that were first described in the form of a research paper.

A research paper is essentially an argument. In a research paper, the authors put together various observations and pieces of data to come to some sort of conclusion. It is written for other scientists, but, because science encompasses many fields, is often written in a way that can be understood by someone educated in science though not necessarily in the field under study.

The format, style, organization, and level of detail of research papers vary depending on where they are published. Some journals, such as Science and Nature, emphasize short papers without a lot of primary data. Others, such as Cell, Genetics, and Genes & Development, are more complete and thorough. In addition to differences in length, the organization of the papers varies depending on the journal. The format described below is a generic one that is presented as a way to consider each part of a research paper. The particular format you follow will depend on the nature of the assignment you have or the journal to which you are submitting a paper.

As a student, you will often be asked to write a research paper as a way to put together experiments that you did and data you gathered as part of a laboratory exercise or a series of laboratory exercises. Note that this type of assignment is different from the laboratory notebook (see above). While the laboratory notebook emphasizes careful note taking and observations, the research paper is a chance to make an argument by synthesizing other studies and your own experiments.

A research paper has several sections, which are described here:

Title. The title of a research paper should be concise; at the same time it should contain enough information that a reader can determine the relevance of the paper to their needs without reading the entire paper. In reports of an experimental nature, the specific information given in the title should include the factors being manipulated and the effects of responses being measured. An example of a self-explanatory title containing the above three elements would be, "Ultraviolet light induces apoptosis via direct activation of Fas/APO-1, independent of CD95L." Avoid cryptic titles such as "A Lab Report" or "Enzyme Action." Such titles give little or no information as to the content of the report.

Another way to think about a good title is to put yourself in the position of a researcher who is going to search a database of scientific literature (e.g., PubMed) using key words to find articles of interest.

Authors. When considering authorship on any paper, the contribution of ideas, materials, experimental results, and the work of writing of the article must all be taken into consideration. In the case of a research paper based on experiments you do as part of a laboratory exercise for a class, you are the first author by virtue of doing all the writing and a large amount of laboratory work to produce the data. The second author is your laboratory partner. The last author on your paper is your TF, acting as the Principal Investigator. The other students in your section have provided additional data for your article and thus should be after your lab partner and before your TF, as scientists who have collaborated in your efforts.

Abstract. This portion of your article should be a summary of your entire report. Without including specific details or references to figures or other studies, provide background, state the principal objectives of your study, describe the methods used, list your most important results and state what you can conclude from them. Similar to the research paper itself, the Abstract should ask and answer a question. In addition, it should be able to stand on its own as a summary of the research; if the rest of the paper were missing, the abstract should still be comprehensible to a reader unfamiliar with the study. Although it comes first, the abstract should be the last thing you write, which will allow you to simply extract key points that you have already written in the body of the report and will ensure that you do not include any information in the abstract that is not in your research article. An abstract is typically between 150 and 500 words in length.

Introduction. The Introduction should provide a context for the topic under study and give the reader the background necessary to understand the rest of the report. As a result, the background will usually be based on previously published material (which must be properly cited). In addition to establishing the context of the problem, the Introduction should provide a concise statement of the problem or goal of the project and a description of the experimental approach(es) used to answer those questions.

Note that an Introduction differs from a Review of a particular topic. While a Review typically covers a topic in detail, the goal of an Introduction is to provide context to understand the question you are asking or the system you are studying. In essence, the Introduction should build to your experimental question. This can be done by describing what is known about a particular topic, to be sure that the reader understands the system, but also considers what is not known or where there is room for additional work.

Materials and Methods. This section describes the specific details of your experiments. As a result, it must provide enough information about the techniques you used to allow the reader to both judge whether the data justify your conclusions and, if desired, replicate your experiments. It is always written in the past tense, as it describes exactly what you did. For example, "The plates were incubated overnight at 37°C."

This portion of a research paper is usually divided into sections labeled with the appropriate subheadings to indicate a specific method (i.e., PCR or Western Blotting). Usually these subheadings are arranged chronologically based on the order of the experimental results presented in the Results section. DO NOT present/discuss your results in this portion of the article, it is meant to be a "how to" guide to your experiments.

How much detail is required? You should provide sufficient detail so that a reader could order the materials you used and replicate the experiment. If a published account is already available (for example, bacterial transformation, PCR, sequencing), the technique itself need not be described in detail again, but you must provide enough information about how you performed the experiment so that it can be independently replicated in another laboratory (for example, in a discussion of PCR, you must provide information about the primers and thermal cycling conditions used, but you do not need to describe how PCR is done). In addition, for all experiments, the name and manufacturer of reagents (including enzymes, bacterial strains, kits, columns, etc.) and relevant instrumentation must be provided. This section should also include sample sizes or number of replications, strain and plasmid names, and other factors known to affect the particular experiment (e.g., temperature, pH, etc.).

Results. In this section, you objectively present the results of your work through descriptive text, figures, and tables. In essence, you are reporting what you observed in each experiment. Briefly state what you did in the experiment, leaving out the plethora of details you included in the Materials and Methods section, describe the key result, and indicate the figure or table containing the supporting data. Remember that the essence of good scientific writing lies in its organization and the distillation of critical results. Refer to the figures and tables parenthetically. This will help you avoid bogging down your writing with a lot of extra words and it will help to keep the reader focused on your key points. In addition, you should avoid explaining every detail of every figure. It is far better to direct the reader to a specific portion of the figure that gives the best demonstration of what you claim is your result. The first one or two sentences of each new paragraph of results should be a transitional statement that explains the logic of why, based on the last experiment, you went on to do the next experiment. Finally, you should avoid drawing conclusions or inferences about the results in this section; save that for the discussion.

Figures and Tables. Figures and tables provide ways to display primary data, such as a photograph of a gel or a Southern blot or a list of numerical data. Each figure and table should be accompanied by a legend. A well-written legend provides enough information about the figure or table that the expert reader (for example, a scientist in a related field) could understand the experimental results by simply looking at the figure or table and reading the legend. In other words, figures and tables are independent units that can be understood without reference to the text. Try this out by going to any journal article and "reading" it by simply glancing at the figures and tables. Note that every figure and table should be referenced in the text.

Discussion. This is the portion of your article where you interpret the results in the context of what is known in the field. The first paragraph should summarize what you believe to be your most important results and what you believe are the best conclusions based on your findings. Then, you may go on to discuss those conclusions in the broader scientific context (i.e., compare them to what has been reported by others in the same area of biology). Discuss the implications of your data and propose future experiments to address unanswered questions. It is important to acknowledge deviations in your data, compared to the results you expected, and explain why those deviations may exist.

References. This final section lists all of the references you cited in the research paper. Every paper you cite in the text should have a corresponding reference in the References section and vice versa. The specific format of the in-text citations and the references listed in this section of the research paper varies depending on the particular journal or assignment. Two rules of thumb always apply, however:

- Follow whatever format is suggested or required. This ensures that the references are formatted in a consistent fashion throughout your paper.
- Watch the details of the suggested format. If a comma is written after the volume number, this means that a comma is required, not a colon, not a semicolon.

Additional information about citing references can be found in Chapter III.

Question:

What types of materials do I need to cite in my reference section?

Answer:

All printed material that you use as a resource to produce your research paper should be included in your references. This includes your class sourcebook, websites, review articles, books, and all primary research literature.

Question:

What is the difference between the Results section and the Discussion section?

Answer:

Think of it this way: R = Report. As a general rule, you should not present any interpretation or draw any conclusions in this portion of your article. D = discuss. The Discussion section is the appropriate place to make conclusions and state your interpretation of the data you have presented. It is your job to consider all possible interpretations before presenting one, which you think, is the best.

Question:

What is the appropriate length for each section of the article?

Answer:

The abstract is the only section that has a pre-defined length, but often there is a word limit for the article as a whole.

Example:

If the word limit is 9,000, the lengths of each section may be something like the following: 300-400 words in the Abstract, 1,400 words in the M&Ms, and 1,000 words for your references. This gives you a remainder of ~ 6,000 to use for your Introduction, Results, and Discussion. As a rule of thumb, these sections should be about equal lengths, leaving you 2,000 words for each.

Research and Grant Proposals

A research or grant proposal is one of the more difficult kinds of writing assignments you will encounter as a student. In addition to understanding the basic components of a research paper (described above), a research proposal requires an additional step. It requires that you ask an original question, develop a reasonable hypothesis or hypotheses, and then come up with a plan for testing that hypothesis or set of alternative hypotheses in the form of an experiment or a series of experiments. If you are writing a real grant proposal, you will eventually do the experiments you describe. If you are writing a research proposal for a class, you are usually not expected to do the experiment or collect any data. Nevertheless, the feasibility of the proposed project is often considered in the evaluation of any proposed project. If you are writing a real grant proposal, it pays off to do some research into the kinds of proposals that are successful with a particular funding agency before you start thinking of the questions that you would like to answer. Some agencies give high points for novelty and creativity while others may prefer proposals that are sound but low-risk. This information may be easily obtained from your advisor or by contacting successful applicants. Usually, these individuals are very helpful and will answer any questions you may have. You can ask to read some of their past proposals. Unless there is a conflict of interest, most grant awardees will be very open to sharing information.

A major challenge of this type of assignment is coming up with a question. This step is difficult because the question has to be one that has not been asked before or one that not been fully answered. In addition, the question has to be answerable in the context of a feasible experiment or a set of experiments. Fortunately, there are places to turn to for help. Keep in mind that questions do not come out of a vacuum. A good place to start is your advisor. A knowledgeable advisor with expertise in a given field of science will be an invaluable source of guidance. This person can direct you to the questions that are currently unanswered within a particular field. Alternatively, he/she may suggest areas of study that have received little or no attention and therefore make them ideal for a proposal. If you prefer a more independent approach or if you are writing a proposal for a class, you can read several papers in your field of interest before coming up with a question. Most papers suggest follow-up experiments in the discussion section. Another good source for a good question is a current review paper. Reviews are written by experts in a given field and they often suggest areas that need more study or questions that remain to be answered.

The format of a research proposal is very important, especially if you are submitting it for funding. Every funding agency expects that submitted proposals be formatted in a very specific way. These guidelines are strictly enforced. A funding agency will turn down a proposal that is not properly formatted. You will also loose points from class assignments if you have not followed directions for the layout. Therefore, be sure to follow whatever guidelines are given to you for a class assignment or for a granting agency.

The text of a research proposal is typically double-spaced, written in a 12-point standard font (Times Roman, Century), 15 cpi (characters per inch), with one-inch margins on all sides.

Make your proposal reader-friendly. You may occasionally use bold or italics to highlight important points. Use headers to organize your proposal. You should indent paragraphs, and unless absolutely unavoidable, skip a line between paragraphs.

The final proposal is comprised of several sections including the following:

- Title Page (optional)
- Abstract or Summary
- Hypotheses and Aims
- Background and Significance
- Preliminary Results (if any)
- Detailed Aims (research design and methods)
- Anticipated Results
- References
- Appendices

The sections in a proposal are distinct from those in a research paper, and these will be discussed in more detail below.

Title Page. Proposals for class assignments often require a Title Page. The Title Page contains the title as well as identifying information, such as your name, campus address, and contact information. The Title Page for most funding agencies is given in a pre-printed format where you need to fill in your information. For both kinds of proposals, the title should be a clear, concise, and accurate description of the goals proposed, while containing enough information so that a potential reader can get the main point of the proposal. Only the first of the three titles, shown on the next page, is specific and direct enough to alert a potential reader to the subject of the paper.

A Comparison of Three Sample Titles

Effective:

- The Process of Nuclear Import Requires Recognition of a Nuclear Localization Signal by α-Importin

Not Effective:

- Importins Assist Entry into the Nucleus
- How Proteins Enter the Nucleus

Abstract or Summary. In the Abstract, key elements of the paper are mentioned. It should serve as a proposal "advertisement;" that is, be simple, interesting and accurate. In the Abstract, you should do the following:

- provide context for your proposal;
- introduce the model system you will be using, and why it was chosen to answer the questions proposed;
- state your hypothesis.
- outline your aims and briefly describe the experimental methods to be used and expected results of each aim.
- explain the relevance of accomplishing the proposed research and how it fits within the larger picture. In other words, how will your research affect other areas?

The abstract or summary should be able to stand on its own without reference to the rest of the Research Proposal. Typically, there is a word-limit for this section, such as 250 words. Although this section appears first to the reader, it is best to save writing it until the end. A good Abstract reflects the entire proposal.

Hypotheses and Aims. It is a good idea to introduce the reader to your hypotheses and aims as early as possible. This section should be brief (one-half to one page long). Funding agencies are increasingly requiring that proposals be hypothesis-driven. Even if what you are proposing to do is more of an exploratory nature (such as a genetic screen or microarray experiment), you should frame it within the context of a testable hypothesis. Your hypothesis should guide the research. Consider the examples provided below. In the first example, the hypothesis is clearly stated. In the second, it is less clear; after reading it, the question remaining is "why?" You should be thorough and state your hypothesis clearly.

You should also include your aims or goals in this section. Your aims should each have a brief description (1 or 2 sentences) of the methodology you propose to use and how the results will be used to test the hypothesis. The number of aims is usually dependent on the amount of time needed to complete the entire project. Short proposals (i.e., summer research) should have one or two aims. Longer proposals (1-3 years) can have up to 3-4 aims. All aims should be related to the hypothesis, and they should be attainable and within your expertise level. You may choose to draw attention to your hypothesis and aims by highlighting (indent or use italics) those sentences. Most reviewers will greatly appreciate this time saver.

Sample Hypotheses

Effective:

> I propose to use molecular systematics to test the hypothesis that two species of the Pan troglodytes clade (P.t. troglodytes and P.t.verus) are able to interbreed successfully.

Not Effective:

> I propose to study the genetic and environmental determinants for key pathways of folate metabolism during human development.

Background and Significance. This section provides context for the research by providing background information on the questions being addressed. This section requires a good and succinct literature review. Include appropriate citations and all relevant information. You should state the rationale behind your proposal and why it is important to answer your specific question. The length of this section varies. If you do not have preliminary results of your own, this section should highlight any research done by others that supports the rationale of your proposal. For short proposals (1-2 pages), this section can be brief and included in *the above overview.*

Preliminary Results. When available, include work you may have done that is relevant to the project. In this section you may include Figures and Tables that show your work. You should refer to the figures within the text (e.g., Figure #). The purpose of this section (when available) is to support the feasibility of the proposed project.

Detailed Aims. Include here the specific methods you will use to accomplish your aims. Describe here the experiments will you need to carry out to accomplish your proposed goals or aims. Also describe the logic and design behind each experiment proposed. You should include enough detailed information for the reader to understand the methodology, but do not give excessive information (i.e., materials used). Consider your experiments carefully – does it really test the hypothesis? What will the outcome tell you? If proposing a new approach, discuss why it improves on current methods used. Try to identify any pitfalls in your experiments and discuss how this will be circumvented.

Example of a Detailed Aim

I propose to use both nuclear and mitochondria DNA to analyze polymorphisms characteristic to each group. This will be done using hair samples from P.t. verus and P.t. troglodytes from wild populations.

Anticipated Results. The name of this section sometimes misleads students. Under this heading, you should consider all of the possible outcomes of your study, not just those you anticipate. In other words, you should consider all the outcomes that you are able to anticipate. The point of this exercise is to think through the design of your experiment. Will your experiment give outcomes that are interpretable? How likely is each of the outcomes? For each possible result, you should discuss how you would interpret it and how it would allow you to discriminate among your hypotheses. Will you be able to meet the goals you set out in your Introduction?

In addition, you should consider how your anticipated findings would change the way we think about the topic and how they fit in the context of the field. This is also the place where you should address potential shortcomings or limitations of your proposed study. You are also welcome in this section to speculate on the generality of your findings and suggest new or follow-up questions or experiments that might stem from your work.

Alternative methods should be included for experimental approaches that may appear risky (not been previously used). It is particularly important to provide alternative methods when the outcome of any aim (i.e., protein purification) is a prerequisite to others (i.e., characterization). The description of the alternative approach should not shadow the initial method proposed. Instead, it should be included as a concise description that strengthens the viability of the project.

References. Provide a reference for each in-text citation. Be sure to follow the suggested format. If not specified, the use of numbered citations is recommended to save space.

Appendices. Any supplemental material, such as photographs or enlarged figures, should be included in the Appendix. Do not use this section to include essential material not included in the proposal because of a page limit. Include tables and figures only if they add to or complement the descriptive text. For example, a figure is sometimes useful to describe a complicated experimental apparatus or biological model. A table is sometimes helpful if your experiment has many variables or many possible outcomes. Tables and figures are placed in that order at the end of the document, after the References.

A Few Final Tips about Research Proposals

- Be objective in your language: test hypotheses, do not try to prove them.
- Discuss your paper with classmates or anyone who is willing to listen. Talking about your ideas often helps to clarify them and others may catch errors that you might have overlooked.
- In addition to consulting published materials, feel free to talk to experts in the field of your proposal, whether they are from Harvard or elsewhere.
- Edit your proposal after you have completed the entire first draft. Editing a proposal before submission is essential. When submitting a proposal to a funding agency, get feedback from different mentors. You want to receive feedback in every aspect of the paper, including the science, grammar and organization.
- Be open to receiving criticism; this will only improve the quality of your final proposal. You should reply graciously to all reviewers' comments and address their concerns if resubmission of the proposal is necessary.

Reviews

A review gives you the opportunity to explore a topic in depth. You get a chance to read the primary scientific literature, teach yourself a topic, synthesize information, and put it all together in the form of an essay. Some students confuse a review with a book report, thinking that the point is simply to report what is known about a given subject or to summarize four or five journal articles in a given field. This is not the case. A review is in fact a creative exercise. A good review not only conveys what you have read and learned, but also takes the next step and comes up with an angle or argument that extends what you have read. What does it mean to take the next step? In this case, it means to evaluate what you have read, synthesize information from various sources, and then come up with a new way of looking at a field. You may put together information in a new way, compare and contrast different pieces of information, explore relationships, or analyze and evaluate primary data. Whatever you choose to do, you should try to analyze and evaluate, not report and list.

Your goal, in other words, is to make a point, to come up with a thesis statement. A thesis statement is simply an argument that you propose and then use evidence to back up. You will recall working on thesis statements in Expos. The thesis statement here is no different. It is a chance to make an original proposal or argument. The strength of this argument will depend on your ability to back it up with evidence from the literature, anticipating and responding to potential objections and counter-arguments, and the organization and structure of your writing.

Coming up with a thesis statement is not easy. You normally begin with a topic, something you want to explore, not a thesis statement. As you read articles and learn about your topic, start taking notes:

- Is something not clear to you?
- Do different authors report conflicting data?
- Do you think it would be interesting to bring together two areas that were previously thought to be unrelated?
- What is particularly interesting about a given topic?
- Is one approach radically different from another?
- Are there assumptions that run through many different experiments?

The answers to any of these questions can serve as a germ of a thesis statement.

Of course, to be convincing, you have to find support for your thesis statement. Be sure that for the angle you choose to take, you can support it with examples from the primary scientific literature. Remember, your goal is to try to convince your reader of the point you are making, and you cannot convince your reader without a good deal of evidence.

A review gives you the opportunity to read papers from the primary literature. This is not an easy task and is therefore discussed more fully in Chapter VI. Reading primary research papers can be difficult, but it is an essential part of being a scientist. It is in a research paper where primary data are reported. You should begin to get used to looking at primary data yourself and coming up with your own interpretations. After all, this is the task of a scientist. What you read in a textbook, what is presented in lecture, what is discussed in a Discussion section of a paper is the result of a distillation process. Someone has looked at the data and come to some kind of interpretation. While most data are real and objective, interpretations are not. Reading the primary scientific literature gives you the chance to look at data for yourself and form your own opinions and interpretations. Were the experiments well designed? Is there an important control that is missing? Were the experiments replicated a sufficient number of times? Are the conclusions sound? Do the interpretations go beyond the data? These are the types of questions that you should be asking yourself as you read the primary literature.

Writing a good review, then, relies on the two aspects of writing that were emphasized in Expository Writing: argument and evidence. You should begin such an exercise by choosing a topic and then researching it. After reading several papers, see if something stands out or might work as a thesis statement. Keep reading and find out if your thesis statement holds up. Then begin writing. Some people like to begin by writing an outline to organize all of their thoughts and information. Others prefer to write quickly and then go back and carefully revise their work. Whatever your approach, you will want to pay particular attention to the first paragraph, in which the direction of your paper and the nature of the problem you want to address are clearly stated. Once you state your case, you will want to support it and build it carefully. Use the information you have collected to make a point, to build an argument.

Writing a review is like taking a photograph. When you take a photograph, you are looking at something that is already out there and capturing it on film. While the resulting image is a representation in most cases of the real world, the photographer does play a creative role. The photographer chooses what to include and what not to include, how to frame the image, what to bring to the foreground and what to place in the background, whether an image is clear or out-of-focus, the amount of light and darkness. In a similar way, the reviewer takes what is out there and distills it through his or her own writing to create something new and original.

Critiques of Scientific Papers

A common assignment in an undergraduate course involves reading one or two papers (either a review and a primary paper, or two primary research papers) and then writing a critique. When dealing with all of the data and details presented in a primary paper, it is very easy to write an unfocused, poorly structured paper.

When writing a critique, it is essential that you write your paper as if you are giving a presentation or lecture about the topic. You probably would not begin a lecture with a critique of the methods used by a particular research group. Instead, you would likely start by providing some broad background information, strategically working your way into the details of your presentation. If your presentation included a critique of the work, you would present the critique only after having provided a solid foundation for understanding your critique. And of course, you would end with a well-crafted conclusion.

You should structure your paper similarly. Begin with a broad introduction: what is the overall field or topic being addressed? What specific question(s) are the authors investigating? What is the main hypothesis of the authors? Continue with your written presentation, describing how the authors test their hypothesis (what is their experimental approach?). Only include specific details about the methods if those details are later necessary for the reader to understand or evaluate a specific point you wish to make. Then provide your critique at the end, after you have explained all the relevant details to the reader. Finally, end with a conclusion that ties your points together.

Writing for the General Public

Writing for a general audience, sometimes called science journalism, presents a special challenge. While a full discussion of this important area is beyond the scope of this Guide, we include a brief consideration of this type of writing here for a few reasons. First, you are likely to encounter at least one such writing assignment as an undergraduate science major, so having a few pointers might be helpful. Second, writing for a general audience can help you sharpen your thinking skills and, in the process, your writing skills. After all, if you can explain a result or research paper to someone else, you probably understand it well. Third, and perhaps most importantly, keeping lines of communication open between scientists and nonscientists is becoming increasingly important as such issues as stem cells, cloning, nanotechnology, global warming, and the like enter the public arena. In this way, writing for a general audience can be thought of as less of a task and more of a responsibility of scientists.

There are aspects of writing for a general audience that are shared with other forms of writing. For example, writing for a general audience requires that you know your audience. At times you need to understand how to summarize, at times simplify, at times explain to get scientific ideas across. You need to understand when you can avoid technical language, as well as when a key term cannot be left out but needs to be explained. You need to understand what background you need to provide and what knowledge can be assumed. Knowing your audience is a key aspect of any sort of writing, even research papers. In this case, you need to keep in mind whether your audience is general, from any field of science, such as when you write for journals such as Science or Nature, or more specialized, as is the case for readers of Genetics or Animal Behaviour. The kind of words you use and the amount of background your provide will vary depending on who you expect to read your paper.

In addition, writing for a general audience is an excellent exercise in summarizing. Often we are asked, when writing for a general audience, to explain an exciting new result or discovery. To do this, we need to fill in the background, describe the key experiment, and convey the major result, all in a relatively small amount of space. Understanding what to include and what to leave out and how to simplify a complicated idea or apparatus is often key to a good piece for a general audience.

While there is no one way to write for a general audience, there is a certain style that often shows up in this form of writing. For example, the paragraphs tend to be short, shorter than you are probably used to in scientific or expository writing. Technical words are often avoided. Important terms that cannot be avoided are carefully explained. Finally, writing for a general audience often begins with a "lead" or "hook," something that is written in a way to grab the reader. For example, the hook may be a simple, dramatic statement of a finding, a narrative, or a twist or surprise from what is expected. However you open a piece for a general audience, and however you write it, you will want to keep the piece moving and your reader interested. Try not to get bogged down in technical explanations or lengthy descriptions, unless it works for the story you are telling.

Chapter III

Writing Strategies and Feedback

The beautiful part of writing is that you don't have to get it right the first time, unlike, say, a brain surgeon.
Robert Cormier

Revising and Editing

Writing is really more about revising than about writing. Revising is such an essential aspect of writing that it warrants special consideration here. Seldom, if ever, do any of us write a first draft and then feel that we are done with a written assignment. Written material is reworked, reorganized, reworded, removed, and rewritten before it really starts to make sense. How you write and subsequently revise a paper can be a very individual process. Some people like to get out ideas quickly, without much attention to detail or organization, and then take the time to rework it into a coherent argument. Others prefer to write more deliberately, taking time and thought with each sentence, even each word, and then spend less time going back over their work. Your approach to the first draft will inform how you end up revising. Nevertheless, there are a few general guidelines that are applicable to any writing style that are worth sharing here.

One important point to keep in mind is that everyone can benefit from revising. We are increasingly accustomed in our society to seeing or doing something once and then moving on. We watch a television show and then turn the television off; we pick up the paper and move quickly from one article to the next; our nightly news is chopped up into increasingly smaller pieces. Writing is different. We need to spend time with the material, think it through, revisit it a number of times, and grapple with the ideas before we can expect to have anything close to a finished work. It is always worth spending this time, even if we are not used to it.

Rewriting serves at least two complementary purposes. The first is obvious; rewriting improves your writing by making sure that you are paying attention to key elements such as content, organization, and style. The second may be less obvious; rewriting helps to clarify your thinking on a subject. It is often the very act of writing, of putting thoughts down on paper, that challenges us to make sure we understand something. And in the act of rewriting, we make sure that the arguments are clear, well supported, and presented in an organized manner.

There are a variety of ways to go about rewriting and one way is not better than another. One strategy for rewriting is to go about it in two phases. In the first phase, pay attention to the major elements of writing: What is the argument? Is it stated clearly? Is the argument well structured? Is the paper well organized? Do the ideas flow easily? Is the argument well supported? Am I using the best evidence? In other words, this is the time to pay attention to such broad issues as argument, content, cohesiveness, and organization. The second, narrower phase occurs once the major elements are in place. Go back and consider some of the details, including elements of grammar, word choice, spelling, and the like. This two-phase approach emphasizes that rewriting does not mean simply going over the paper for spelling mistakes. Rewriting involves looking at what you have written and making sure you are saying what you want to say.

Here are a few basic guidelines to keep in mind as you revise your own papers:

- Consider going through at least three drafts as you revise; four to five drafts are not unreasonable.
- Try reading your paper aloud. Sometimes listening to your written work is the clearest way to spot problem areas, difficulties with logic, and grammar mistakes.
- Do not be afraid to make major changes to your work. While sometimes it is hard to discard hard-won sentences or reorganize a beloved passage, keep in mind that your ultimate goal is to put together a coherent, well-articulated paper. If a word, sentence, or passage is not working, or if the organization does not serve the argument, a major change may be just the thing.
- Print out your paper. In the editing and revising process, it is often useful to see several pages at once and not be confined to what fits within the limited space of a computer screen.
- Be aware of and address your writing weaknesses. By the time you reach college, you hopefully have had enough feedback on your writing to at least

have some idea of your strengths and weaknesses. Knowing your weaknesses and rewriting with an eye towards these is very helpful. If you know you have trouble with transitions, ask yourself whether each paragraph flows easily to the next. If you have been told that you rely too heavily on secondary sources, ask yourself if you have used and cited the best primary evidence. In other words, know and explicitly address problems that you know you have.

- Realize that your computer spell-check will not catch all of your spelling mistakes. For example, it will not pick up words that are misspelled but become other words, such as is/if or deaf/dear. It also does not do a very good job with technical words, sometimes even automatically changing a correct word to something entirely inappropriate.
- Come at your paper with a fresh eye. The word "revise" after all means to see again, and it is hard to see something again without a bit of time between drafts. This often means leaving your paper for a day or two and then returning it. Of course, to do this means completing one or two drafts well in advance of the due date. While this may be difficult, such planning often pays off in terms of being able to get some distance from your work.
- Seek help from the peer tutors at the Harvard Writing Center (Appendix) or from your House academic writing tutor (if your house has one).

Evaluation of Student Writing

The evaluation of student writing in the sciences follows many of the same criteria used to assess student writing in general. Criteria for five elements of writing are most emphasized by the Expository Writing Program in the evaluation of student writing, and it is useful to be aware of these, not just for the sake of improving your grade, but because they reflect basic elements of good writing. These elements are the following:

- Thesis: Is there a main argument in the paper? Is it clearly stated? Is it interesting and complex? Is it well argued throughout the paper?
- Structure: Is the paper organized clearly? Is it easy to understand the main point of the paper, the main point of each section, the main point of each paragraph? Does the order of the overall argument make sense? Is it easy to follow? Are there appropriate transitions linking the various ideas?
- Evidence and Sources: Does the paper give supporting evidence for each of its points? Does the paper suggest that the writer has a good grasp of the subject matter and the field in general? Has the paper missed any obvious or important pieces of evidence? Is the evidence properly attributed and is the reference information correct and properly cited?
- Analysis: Is there enough analysis of the evidence? Is the analysis appropriate? Are the conclusions sound?
- Style: Is the style appropriate for the assignment and the audience? Is the paper concise and to the point? Are sentences clear and grammatically correct? Is the paper free of spelling and proofreading errors?

These five elements apply to writing in general as well as to writing in the sciences, so it is useful to keep them in mind in your own writing.

Common Mistakes in Scientific Writing

Certain mistakes show up repeatedly in student writing. Here, we have compiled the most common writing mistakes that we have found. They are worth paying attention to, as getting these details right will allow the reader to focus on what you want to say, without being distracted by simple, avoidable errors. While some of these pertain to writing in the sciences, many are relevant to writing in any field.

Formatting Conventions

- Pages should be numbered; the first page usually does not have a number because it is understood that it is page one.
- Avoid series of parentheses, such as: (Davis 1999)(Figure 1). Combine the information: (Davis 1999; Figure 1).
- In-text citations are always inside end punctuation: "…higher fitness (Lewontin 1976)." Not "…higher fitness. (Lewontin 1976)"
- Each in-text literature citation must have a full citation in the References section and vice versa.
- Figures and tables should be numbered in the order they appear in the text.
- Figures should be cited as (Figure 1) or (Fig. 1), not (see Figure 1) nor (see Figure 1 attached), etc. The same rules apply for references to tables.

- During the publication process, figures (photos and graphs) are usually scanned or photographed and added to the layout in the appropriate place. All text, including figure captions and tables, are word processed and added to the layout as text, not as a graphic. For this reason, figure captions should be listed on a single sheet (the last page of text before the figures), and the figures should be camera-ready with no captions on the same piece of paper (letters and numbers in the figure will become a graphic element). Note that, while it is important to layout a table so that it is easy to interpret, journals will reformat tables to conform to their standard table style.
- If you use an abbreviation, you should define it after its first use in the paper. For example, "The vomeronasal organ (VNO)...." After this, simply use VNO.

Scientific Usage Rules and Conventions

- Gene names and their abbreviations, as well as Latin words and their abbreviations, should be in italics: *e.g.*, *ultrabithorax*, *ubx*, *ergo*, *in situ*, *et al.*, *etc*. Note that some journals choose to ignore these rules.
- "Data" is the plural of "datum." Therefore, "…the data were collected…." not, "the data was collected."
- The plural of species is species; the plural of genus is genera.
- The word "prove" is generally avoided outside of mathematics. In science, you cannot prove a hypothesis. The best you can hope for is that your hypothesis is supported by the data, or that your data

are consistent with your hypothesis. If an idea repeatedly stands up to experimental scrutiny and is consistently not disproved, then it becomes relegated to the status of a theory, such as the Theory of Evolution or the Chromosome Theory of Inheritance.

- Be careful of attributing intent to organisms when talking or writing about evolution. Birds did not evolve wings in order to fly. Natural selection does not work with a particular goal in mind, such as flight. Instead, it works through random variation followed by differential survival and reproduction. While suggesting that birds evolved wings in order to fly is a convenient shorthand, it misses the fundamental principle of evolution by natural selection.
- Be aware of tense. The results of others are usually discussed in the past tense, "Smith and colleagues (1998) found that…." The Methods section of a research paper is also written in the past tense (it has already been done by the time the paper is being written). However, the results section of a paper is written in present tense. Grant proposals describe procedures that have not yet been done, and should be written in future tense.
- A scientific name is composed of two words: a genus name and a species epithet. The first letter of the generic name is always capitalized and the specific name is never capitalized. Both words must be written in italics or underlined. Generic names should be written out in their first appearance in the title, abstract, and main text. If they are subsequently mentioned in one of these locations, they may be abbreviated. It is also advisable to mention

the English name for your critter once or twice. For example, "Caterpillars of the lycaenid butterfly *Jalmenus evagoras* were studied…." Later, "*J. evagoras* caterpillars were studied…." While most scientists know that C. elegans is a nematode worm, it is helpful to provide a common name for lesser known organisms. The generic names of some common model organisms, e.g., Drosophila and Arabidopsis, are now used as common names, too. When these names are written in isolation, they are being used as common names and are not italicized. In conjunction with a specific epithet they are scientific names and must be italicized. A final note: *Jalmenus* sp. refers to a single unspecified species in the genus *Jalmenus*. *Jalmenus* spp. refers to two or more species in the genus Jalmenus. Note the use of italics on these intentionally ambiguous names.

General Comments

- "Between" is used for two things; "among" for three or more. So, "the caterpillars were distributed among the three plants," not "the caterpillars were distributed between the three plants."
- Do not use "however" as a conjunction, as "Doxorubicin is a useful chemotherapeutic agent, however severe cardiotoxicity limits its use." This sentence is a run-on. *However* requires a semicolon or period preceding it and a comma after it, as "Doxorubicin is a useful chemotherapeutic agent; however, severe cardiotoxicity limits its use." The same holds true for "therefore."
- Be careful with word pairs that are often confused: that/which, affect/effect, its/it's, choose/chose,

advice/advise, accept/except, proceed/precede; between/among; less/fewer.

- The words "who" and "whom" refer to people; they cannot refer to animals.
- It is not appropriate to use first person plural in a single authored work. For a single authored work, use "I." For two or more authors, use "we."
- Avoid strings of prepositional phrases: "Several regions of the brain have been implicated in the recognition of kin," might be written, "Several brain regions have been implicated in kin recognition."
- Avoid overused expressions and clichés.
- Strive for verbal variety; do not begin every sentence in a paragraph with "I."

Chapter IV

Finding and Using References

The most erroneous stories are those we think we know best—and therefore never scrutinize or question.
Stephen Jay Gould

Finding References

If you have tried your hand at any form of scientific writing, or if you have reached this point in the guide, you can see that scientific writing makes use of many kinds of references. Therefore, knowing how to find and cite these references is key and warrants attention here. In addition to this chapter, a very useful guide to the use of references is Harvard's Writing with Sources (Appendix A), which provides a more complete treatment of the issues that are touched upon here.

There are two general kinds of sources that you will come across in scientific writing: primary sources and secondary sources. Primary sources report original experiments, data, and ideas. They usually take the form of research articles and can be found in scientific journals, such as Science, Nature, Cell, Genetics, Animal Behaviour, and Evolution. Other primary sources that show up less frequently include dissertations, technical reports, and conference abstracts and papers. Secondary sources, as the name suggests, are one step away from the primary data. They include such sources as textbooks, review papers, and articles in popular science magazines, such as Scientific American, Natural History, and Discover. These are generally written for a general audience and summarize many experiments and papers. Most websites on a scientific topic that you will encounter summarize experiments and data, and are therefore considered secondary sources. However, primary data are sometimes reported on the web, in which case that website would be considered a primary source. For example, DNA sequence data are now frequently found on the web.

As you write your own science papers, you will want to turn increasingly to primary sources. Primary papers describe experimental methodology and report original data. Learning how to evaluate an experiment critically and interpret data for yourself is an important aspect of being a scientist (Chapter VI). While the secondary literature is often a great place to start, you will want to seek out and read the primary literature on which the secondary sources are based.

So how do you go about finding sources for your papers? There are two general ways. The first is to follow a paper trail. Start with the secondary sources, such as your textbook or a scientific review. These are often heavily cited and highlight major works in a particular field. From there, read the primary papers that are referenced. Again, the literature cited section of these primary works will be filled with additional papers that are relevant to the area you are exploring. In a short amount of time, you will start seeing the same reviews and primary articles showing up again and again, and this will give you an indication that you have found most of the important or key references on a given topic.

A second, complementary approach is to use computerized, searchable databases. There are several excellent internet-based databases of science references and you should begin to familiarize yourself with them. These are readily searchable, allowing you to type in a subject, key word, author, or other search term and pull up hundreds, if not thousands, of references. The challenge of using these databases, then, is not finding references, but identifying which ones from the list are most useful to you. Knowing how to narrow your search is often key in the effective use of these databases. The most widely used databases in the biological sciences include Medline, Science Citation Index, Current Contents, and Biological Abstracts (Appendix A). These are best accessed through the Harvard University Library website (http://lib.harvard.edu), as Harvard has licensing agreements that give you access to those that are otherwise restricted.

When to Cite

At this point in your education, you are probably familiar with the basic rules of citation. You know you are supposed to provide a reference following a direct quotation or when you borrow or make use of another author's idea. While these two rules certainly apply to writing in the sciences, they actually do not come up very often. Direct quotations are seldom seen in scientific writing. If you use a direct quotation, you should think very carefully whether the exact words are really required, or whether paraphrasing might be sufficient. In either case, you will need to provide a reference for the idea or thought. However, a direct quotation in student writing in the sciences often indicates that the writer did not fully understand what was written. After all, it takes understanding to be able to paraphrase someone else's work. Only use a direct quotation if the particular words carry significance that cannot be conveyed by paraphrasing.

Citing comes up most often in scientific writing in two other scenarios. The first is when you report the results or conclusions of a particular study. In this case, you can cite the study as, "Darwin (1859) suggested that evolution occurs by means of natural selection" or as, "Evolution occurs by means of natural selection (Darwin, 1859)."

The second, often overlooked scenario for citing is when you want to direct the reader to additional reading. For example, if you write, "T cells are known to be important in the immune system," it is helpful to cite a recent review on the topic or several key recent papers or even an older, original reference if it is not cited in a recent review. This kind of citation directs the reader to additional sources if he/she is interested in pursuing the topic further.

When you cite references in either of these situations, it is useful to provide the reference or references up-front, at the first mention of the study or idea. In other forms of writing, the citation is often held to the end of the paragraph in which you talk about someone else's ideas or thoughts, as a way to signal that the entire paragraph relies on that work. In science, however, the citation is provided early, following the first sentence, so that a reader familiar with the study or idea will instantly know what work you are discussing. Even if the rest of the paragraph continues to refer to the same study, you do not need to keep repeating the citation. It is understood that the early citation is the source under discussion.

How to Cite

References are cited in two places in scientific writing, in the text and at the end of the document in a dedicated "References" section. The format of the citations in these two places is very important. Different journals, funding agencies, and classes follow different and often idiosyncratic formatting styles. The task is simply to follow the format that you are provided. So, if you are submitting a paper to the journal *Behavioral Ecology*, you should follow the format of that journal. Most journals have a special "Instructions to Authors" section on their website that spells out in detail how to format references. Another approach is simply to follow the format of the references in a recent article from that journal. Similarly, if you are submitting a grant to the National Science Foundation, you should find and follow those formatting guidelines. Most writing assignments for your college classes will also specify a particular style, either from a journal or another source.

Whatever style you are asked to follow, it is important to follow it. While this sounds simple, it apparently is not, as instructors constantly receive incorrectly formatted references even when explicit directions are given. A comma does not mean a semicolon, and bold type is not the same as plain type. For example, the American Psychological Association (APA) provides specific formatting guidelines for references. A student who was asked to follow APA guidelines came up with the following incorrect reference:

> A. E. Newsome, 1965. "The abundance of red kangaroos in central Australia." <u>Australian Journal of Zoology</u>. 13: 269-287.

Can you spot all of the formatting errors above? The correctly formatted APA citation is provided here:

> Newsome, A. E. (1965). The abundance of red kangaroos in central Australia. *Australian Journal of Zoology,* 13, 269-287.

At this point, you might think that this level of detail is trivial at best. However, there are several reasons why citation format is important. First, as a scientist or physician, a journal article submission or grant will be returned unread if the specified format is not followed. Second, following a particular style will ensure that your references are consistently formatted. Finally, different formatting styles convey different kinds of information. For instance, the (author, year) style for in-text citations of APA or *Cell* provides information to a reader familiar with a field that a particular study or work is under discussion. Alternatively, use of footnotes for in-text citations, as is required for papers in

Science or *Nature*, saves space and allows for multiple references to be grouped together.

In summary, while there is no specific format that should be followed for all of your writing assignments in the sciences, a few general guidelines apply. First, always follow the format that is suggested in a given writing assignment. The format is usually specified or spelled out in detail; if so, it is not meant as a vague suggestion, but instead is intended as an explicit direction. Second, watch details. Different formats and style sometimes differ in small ways – a comma here, a semicolon there – and part of the task of following a particular format is just that, to follow the format. While this might seem like a trivial exercise, the work of a scientist in part involves writing papers for publication or grants for funding, where following proper format is crucial. Third, unless otherwise stated, in-text citations should normally be in the form of (author(s), year), rather than in the form of a footnote, since the former conveys a lot of information to a reader familiar with the topic. Footnotes are generally used in scientific writing only when space is severely limited, which is typically not the case in student writing assignments.

Chapter V

Related Skills

Reading usually precedes writing and the impulse to write is almost always fired by reading. Reading, the love of reading, is what makes you dream of becoming a writer.
Susan Sontag

Reading the Scientific Literature

The scientific literature is a published account of work done in a particular field and is the predominant way in which experimental findings are communicated. The scientific literature is comprised of two types of publications: primary research articles and review articles. Primary research articles are typically written by the group of scientists that performed the experiment or experiments being described and contain background information outlining the rationale for performing the experiments, details about the materials and methods used to conduct the experiments, the results (data) obtained from the experiments, and the authors' analysis and interpretation of the experimental findings.

Review articles, on the other hand, contain very little (if any) experimental data; the purpose of a review article is to summarize and synthesize the findings of one or more primary research articles and to put those findings in a broader context that is accessible to a wider readership. Review articles may or may not be written by the scientist(s) who performed the experiments, although they are almost always written by scientists having an expertise in the subject matter of the article. Review articles often present alternate interpretations of the data reported in a primary article, synthesize data presented in multiple primary research articles into a single model, and provide suggestions for further research in the field.

What about textbooks - are they considered part of the scientific literature? Not really. Textbooks distill information contained in primary research and review articles in order to present a "broad overview" of a particular subject – in many cases, a single textbook chapter may distill information gathered from hundreds of experiments carried out over many years! Most textbooks contain very little experimental data and almost never provide a detailed description of the experimental materials and methods. Although textbooks are extensively reviewed and edited by experts in the field, they occasionally contain oversimplified models and/or analyses based primarily on current opinion in a given field, so you should always keep in mind that textbooks are not a list of undisputed scientific "facts."

It is important to gain experience reading the scientific literature for two reasons. First, the most up-to-date experimental data and ideas are communicated as primary research articles and review articles, and so all scientists must be proficient at reading the scientific literature to stay current in a particular field. Since these most current findings are not available in textbooks, most scientists use textbooks only as resources for gathering background information on topics with which they are unfamiliar.

Second, reading the literature encourages you to think like a scientist. Since the literature contains actual experimental data and procedures used to reach conclusions, it enables you to critically examine the authors' interpretation and analysis of the data – do you believe what they are telling you? By examining the experimental data and understanding how the authors reached their conclusions, you are being exposed to the "thought processes" of a group of scientists (the authors) and challenging yourself to think like a scientist.

Because the information contained in a research article is compartmentalized, scientific papers are typically not read straight through like a novel; reading a scientific paper is not a unidirectional process. To fully comprehend how the experiments were carried out, understand the data, and critically examine the authors' analysis and interpretation of those data, you will probably need to flip back-and-forth between sections and will usually need to read the paper multiple times.

The ability to effectively read the scientific literature is a skill that is acquired over time. In this guide we offer some suggestions on how to begin reading primary research articles from the scientific literature (to help you prepare for an assigned reading, for example).

It is important to note here, there is no single correct way to read a paper. The manner in which you read a paper will depend on many factors, including your familiarity with the subject matter and the length and format of the paper (both of which will vary depending on the journal where the article was published).

An additional factor that will influence how you read the paper is knowing what you hope to gain from your reading. Are you reading the paper out of own interest, for an assignment in a course, or in order to replicate an experiment that has been described in the literature? Alternatively, perhaps you are gathering background information for your undergraduate thesis project, preparing for your Ph.D. dissertation defense, writing a grant application to fund a research project in your laboratory, or reviewing/critiquing an article submitted by another scientist prior to publication. For each of these scenarios, you would probably read the paper in a different manner, by focusing your attention on different aspects of the paper.

Below, we offer some suggestions on how to read a primary research article, assuming that you have little (or no) experience reading the primary literature and that you are reading the paper to fulfill an assignment in an undergraduate biology course. Experienced readers will probably find they already use some of these techniques, but hopefully all additional tips will be useful for further improvement.

Step 1: Read the title and abstract. This step will help you determine if the paper is appropriate for your needs (unless you have been assigned the paper, of course – then you have to read it!). Pay particular attention to the following questions:

- What hypotheses are the researchers addressing?
- How do they test their hypotheses (what is the experimental design?)
- What are the overall findings of the paper?

Do not worry if you cannot answer all of these questions from reading the abstract alone; you will be able to by the time you have grappled with the paper a bit.

Step 2: Read the introduction carefully and take notes. A well-written introduction should lead you directly into the results section by setting you up to understand the experiments presented in the paper. If necessary, do some supplementary reading (you might find it helpful to refer to a textbook or to papers that are specifically referenced) if you need additional background information on the topic(s) discussed in the paper.

Note that if you are a practicing scientist and if the paper is in your primary field, you may choose not to read the introduction because you will be very familiar with the experiments leading up to the work. However, most students should read and understand the introduction, because it is in the introduction that relevant background information is communicated to the reader.

Step 3: Go through the entire paper one figure at a time. The figures are where the data are presented and are therefore one of the most important parts of the paper. Jot down any acronyms you encounter and try to determine what experimental technique was used to obtain the data presented in each of the figures (Southern blot, polymerase chain reaction, Western blot, immunoprecipitation, etc.). This will help prepare you to read the results and discussion sections. Do not worry if you do not understand all of the experimental techniques used in the paper – you will probably understand them better when you actually read the results and discussion.

Note: many scientists "read" the paper simply by looking at and understanding the figures, reading the accompanying text only as necessary to understand the data presented in the figures. Write notes to yourself about the data, its significance and any questions you have as you go through them.

Step 4: Begin reading the results (or results/discussion) section. As you read the results section, you will frequently come across parenthetical references to the figures. Carefully examine the data and text presented in each figure/figure legend as you read along, supplementing your understanding of the experiment with the text in the results section, and, if necessary, the materials and methods section. Repeat this process for each of the figures in the paper, until you are confident that you understand the data presented in each figure. Understanding the figures is so important that a good rule-of-thumb is that you should be able to draw out the results on a blank sheet of paper and be able to explain them to a friend using plain English words.[1]

You will likely have to flip back-and-forth, gathering relevant information from the figure legends, materials and methods, results, and perhaps even the discussion sections in order to thoroughly understand the data presented in each of the figures. By the time you have completed this stage of the reading, you should have defined all of the acronyms you jotted down when you skimmed through the paper and you should be familiar with each of the experimental techniques used to collect the data. If not, you should do some background reading on topics that remain confusing, utilizing textbooks and online resources (such as the "books" search engine at the National Center for Biotechnology Information[2]).

Step 5: Read the discussion section. Once you understand the results reported in the paper, it is time to tackle the discussion section. The text in the discussion section provides the authors with the opportunity to put their findings in a broader context: What conclusions can be drawn from the findings? How do the findings fit within the field as a whole?

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[1] http://helios.hampshire.edu/~apmNS/design/RESOURCES/HOW_READ.html

[2] http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=Books

Oral Presentations

Many science classes require some sort of oral presentation that you make to the rest of the class. An oral presentation is usually done to present a scientific paper or review a particular topic. While this is obviously not a writing assignment, a brief discussion is included here as many of the same principles apply, including clarity, organization, and ability to communicate. In addition, if you go on in any field, be it in science, medicine, business, or teaching, you will frequently revisit the oral presentation.

There are very few people who have a natural talent for delivering outstanding presentations. However, planning, some hard work, and practice can carry the rest of us to a very good level.

Many students ask whether they should use overheads or PowerPoint in their presentations. While you should follow whatever guidelines are suggested, a useful rule-of-thumb is that the point of an oral presentation is to communicate information to others. Therefore, you should use whatever medium will help you communicate. If PowerPoint will help you get your point across, then use it. If the blackboard is more effective, then that would be the route to choose. In other words, the specific medium you choose is less important than your ability to communicate. We have probably all seen very effective presentations that are done without visual aids, as well as PowerPoint slides that do not add to, and sometimes detract from, the presentation. This section highlights a few things to keep in mind if you are asked to present a scientific paper to the rest of your class.

Initial planning. This is a key step. What sort of talk is it? How long is supposed to be? Who is your audience? What information are you expected to convey? Be sure you are clear on these points before moving on to the next steps.

Read the paper. If you are asked to summarize a paper, take time to read it carefully, paying particular attention to the central question and hypothesis, methodology, results, and how the paper fits in the overall theme of what you are covering in class. You will probably need to read the paper several times, first to get the general questions and ideas, and then to understand the details. Sometimes it is important to look up, read, and discuss a key paper or two that preceded the paper you are presenting, particularly if your paper directly follows in the scientific footsteps of previous work.

Preparing the presentation. Once you understand the paper and know what you want to say, you will have to decide how to say it. Unlike a conversation, an oral presentation is a one-shot attempt to convey information and make a point. It is essential that your talk be well organized and that your points are presented to the audience in a logical sequence. One example of a logical sequence for the presentation of a scientific paper is to describe the background, question(s), hypothesis, methods, results, and significance of the data. Paying attention to these elements, in this order, is often useful as a way to organize the presentation and communicate the paper. It is often helpful to include a presentation of at least one key figure from the paper. This demonstrates that you understand the one or two key findings of the paper and it is also a good chance to for you to explain and interpret a figure, designate axes, describe the figure's significance (or lack thereof), etc. It is often more effective to present the figure on an overhead, PowerPoint, or blackboard rather than have the students all refer to it in a handout so you can describe it to the class. Finally, be sure not to get lost in the details. While some level of detail is important, be cautious about explaining every detail in the context of a 15-20 minute presentation. Timeliness is at least as important as thoroughness in this context.

Visual Aids. Many students ask whether they should use overheads or PowerPoint in their presentations. While you should follow whatever guidelines are suggested, remember that the point of an oral presentation is to communicate information to others. Therefore, you should use whatever medium will help you communicate. If PowerPoint will help you get your point across, then use it. If the blackboard is more effective, then that would be the route to choose. In other words, the specific medium you choose is less important than your ability to communicate. We have probably all seen very effective presentations that are done without visual aids, as well as PowerPoint slides that do not add to, and sometimes detract from, the presentation.

Questions. Sometimes, depending on the context and assignment, a nice way to end an oral presentation is with a class discussion. Prepare a list of relevant questions that you think will stimulate a discussion. Open-ended questions are far more useful for generating discussion than questions that quiz everyone on the factual details of the paper. Many interesting discussions result from connecting information and concepts from other disciplines, such as neurobiology, biochemistry, genetics, psychology, economics, mathematics, etc. Here are some examples of questions to aid you in your own question-writing endeavors:

- How universal are the conclusions from this experiment?
- What assumptions do the authors make?
- Can you think of a way to improve the experimental design?
- Do you think the experiments are well controlled?
- How do the results and conclusions connect to what you are learning in class?

Rehearse. One of the most important aspects of preparing an oral presentation is to rehearse. Do so by yourself at first. Then for a real test, practice your presentation in front of friends, classmates, or colleagues. As you rehearse, be sure to pay attention to some key elements of oral presentations:

- Opening. The opening should catch the interest and attention of the audience immediately. This is also the place to avoid technical jargon.
- Transitions. The links between successive elements of the talk should be planned carefully so that they are smooth and logical. You should make the connections between each part clear to the audience.
- Conclusion. Try to help your audience understand your main points by including some sort of wrap-up or conclusion at the end. It is useful to signal that the summary is beginning explicitly.
- Rate. Don't talk too quickly or you will lose your audience. People tend to speed up when they are nervous, so you may need to practice talking more slowly than you think. Use pauses where appropriate and repeat critical information.

- Time. A 20-minute talk should be a 20-minute talk, not a 30-minute talk or a 10-minute talk. While this point sounds obvious, this is a typical place where many presenters have trouble. The audience may get antsy if a 20-minute talk starts going on too long with no signs of finishing. Part of planning a presentation is to make sure it does indeed fit into the allotted time. When you practice, be sure you time your presentation.

Active Listening

Listening is often taken for granted. However, active listening is an essential, but often overlooked and underpracticed, skill in scientific and academic endeavors (and in many other areas as well). Again, a full discussion of active listening is beyond the scope of this Guide, but a few characteristics of active listening will be highlighted here[1].

- Be attentive. Focus your thoughts and attention on the presenter.
- Do not interrupt.
- Be able to restate the person's key points and important thoughts.
- Be mindful of your non-verbal behavior such as posture, eye contact, facial expressions, and gestures.
- Keep in mind that active listening is personally enriching.

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[1] Adapted from Joan Sturkie and Valerie Gibson, Peer Counselor's Pocket Book, San Jose: Resources Publication, 1989.

- Avoid mentally arguing with yourself or with the other person while s/he is speaking.
- Do not antagonize the speaker with hasty judgments.
- Avoid making premature conclusions.
- When the speaker is finished, be ready with a question or two that shows you listened, understood, and are actively thinking about what was said.

Appendix

Additional Resources

Writing Support Services at Harvard University

Harvard University Writing Center
Barker Center 019
12 Quincy Street
Cambridge, MA 02138
617-495-1655
http://www.fas.harvard.edu/~wricntr

Pre-scheduled conferences with trained peer tutors are offered Monday through Friday, 9 - 5PM; drop-in hours are offered Sunday through Thursday, 7 - 9PM. Always check the website for location of drop-in hours. (During the week, you need to arrive no later than 8PM to guarantee a slot.) You are also welcome to drop in during the day, and, if one of the tutors is free, he or she will gladly meet with you at that time.

Bureau of Study Counsel
5 Linden Street
Cambridge, MA 02138
617-495-2581
e-mail: bsc@fas.harvard.edu
http://www.fas.harvard.edu/~bsc

You should also check to see if your house has a resident or non-resident writing tutor.

Useful Websites on Writing

Writing Center's "Writing Tools"
http://www.fas.harvard.edu/~wricntr/html/tools.htm

Writing with Sources
http://www.fas.harvard.edu/~expos/sources

Lamont Library's Website for Student Writers
http://hcl.harvard.edu/lamont/resources/guides

University of Chicago Writing Program
http://writing-program.uchicago.edu/resources/grammar.htm

Searchable Online Databases

Medline (U.S. National Library of Medicine)
Follow links to PubMed from the homepage of the National Center for Biotechnology Information (NCBI) home page at http://www.ncbi.nlm.nih.gov/ for access to abstracts only or to Medline from Harvard University Library e-resources link at http://lib.harvard.edu for full access.

Science Citation Index (Institute for Scientific Information, or ISI) Follow links to Science Citation Index from Harvard University Library e-resources link at http://lib.harvard.edu for full access.

Biological Abstracts (BIOSIS)
Follow links to BIOSIS from Harvard University Library e-resources link at http://lib.harvard.edu for full access.

Harvard University Libraries
Access website at http://lib.harvard.edu, follow link to e-resources, then choose journal or database. Your identification number and PIN will give you access to all sources with

which Harvard has a licensing agreement, including Science Citation Index and BIOSIS.

Suggested References for Further Reading

Harnack, A., & Kleppinger, E. (2003). Online! A Reference Guide to Using Internet Sources. Boston: Bedford/St. Martin's.

O'Brien, E., Rosenzweig, J., & Sommers, N. (2004). Making the Most of College Writing: A Guide for Freshmen. Cambridge, MA: Expository Writing Program, Harvard College.

Pechenik, J.A. (2004). A Short Guide to Writing about Biology. (5^{th} ed.). New York: Pearson Education, Inc.

Strunk, W. Jr., & White, E.B. (2000). The Elements of Style. (4^{th} ed.). Needham Heights, MA: Allyn & Bacon.

Trus, L. (2003). Eats, Shoots & Leaves: The Zero Tolerance Approach to Punctuation. New York: Gotham Books.

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