SAINT JOSEPH COLLEGE
CONNECTICUT
CENTER FOR ACADEMIC EXCELLENCE

Helpful Tips & Links for Writing in Chemistry & Biology

Section	Scientific Method Step	As well as...
Introduction	Describes the context and states your hypothesis	Explains how you derived that hypothesis and how it connects to previous research; gives the purpose of the experiment/study
Methods	Details how you tested your hypothesis	Clarifies why you performed your study in that particular way
Results	Provides raw (i.e., uninterpreted) data collected	Expresses the data in table form, as an easy-to-read figure, or as percentages/ratios
Discussion	Considers whether the data you obtained support the hypothesis	Explores the implications of your finding and judges the potential limitations of your experimental design

* For more helpful detailed information on how to write a chemistry lab report, i.e. writing a strong introduction, stating the proper purpose, forming an adequate hypothesis, content, materials & methods, overall structure and style, correctly stating and displaying your results, proper use of tables and figures, writing a strong discussion, etc.

Visit: ***http://www.unc.edu/depts/wcweb/handouts/lab_report_complete.html***

General Format & Components

Abstract

A brief statement summarizing what was done and why and giving the principal results. It should be complete enough so that one need not read the paper to understand the abstract. Everything in the abstract is repeated, but with more elaboration, in the paper. The purpose of the abstract is to allow the reader to determine whether or not it will be worthwhile to read the entire paper.

Introduction

The introduction provides the background and theory motivating the experiment. What is the purpose of each one of your experiments? It may contain brief descriptions of previous work done on the subject. You may also want to frame a hypothesis for what you intend to test, at the end of this section. The introduction typically starts with the "big picture" and leads the reader down a narrowing path to the purpose of this particular study. It provides the reader with context and the background information necessary to understand the context in which the results of the study will be placed.

Materials and Methods

The experiment must be described thoroughly, but concisely. The description should cover all apparatus used (including manufacturer's names and model numbers), diagrams of experimental

arrangements, and a detailed discussion of techniques and procedures. The experiment should be written so that someone could perform the experiment based on what you wrote. The description should be in the past tense as it describes what was done. It is not a recipe of steps to do, as are often requested in chemistry lab reports. Often standard protocols are cited with descriptions of how those procedures were altered or modified in this particular study.

Results

You may present data, observations, and results in tabular form and/or graphically, in addition to a written statement of your findings. Include a description of any mathematical manipulations of the data. This is the section in which you state your findings, not analyze what they mean or how you got them. The "how you got them" goes in the methods. The "what they mean" goes in the discussion.

Discussion

Draw conclusions about the results and interpret what these results mean. While speculations are sometimes appropriate in this section, opinion must be carefully distinguished from conclusions that are supported completely by evidence. Discuss any limitations of your study, including human error or issues with the materials. Consider addressing the significance of this study in relation to others. This section closes the loop. You provided a context for the study in the introduction. Here you discuss your findings within that context. Sometimes acknowledgements go here.

References

This is a bibliography or list of footnotes. Consult the instructor about what style guide to follow for these entries.

Tips:

- A key ingredient for writing a good laboratory report is taking good lab notes and writing down observations
- Always keep your audience in mind.
- The purpose of the report is to convey what you have done in a concise, organized, and easy to read fashion.
- Past tense should be used to describe what you did in lab. Present tense should be used for statements of fact and chemical properties. For example: "The melting point of unknown 3319801 was measured to be 109°C. The melting point of acetanilide is 114°C."
- Avoid using the first person and any statements of how you "felt" about an experiment, whether it was "easy," or the supposition that you "learned a lot" from the lab.

http://www.uah.edu/writing/Word_files/lab_tips.doc.

General Guidelines

- Print or type using a 12 point standard font, such as Times, Geneva, Bookman, Helvetica, etc.
- Text should be double spaced on 8 1/2" x 11" paper with 1 inch margins, single sided
- Number pages consecutively
- Start each new section on a new page
- Adhere to recommended page limits

Mistakes to avoid

- Placing a heading at the bottom of a page with the following text on the next page (insert a page break!)
- Dividing a table or figure - confine each figure/table to a single page
- Submitting a paper with pages out of order

In all sections of your paper

- Use normal prose including articles ("a", "the," etc.)
- Stay focused on the research topic of the paper
- Use paragraphs to separate each important point (except for the abstract)
- Indent the first line of each paragraph
- Present your points in logical order
- Use present tense to report well accepted facts - for example, 'the grass is green'
- Use past tense to describe specific results - for example, 'When weed killer was applied, the grass was brown'
- Avoid informal wording, don't address the reader directly, and don't use jargon, slang terms, or superlatives
- Avoid use of superfluous pictures - include only those figures necessary to presenting results

Title Page

Select an informative title as illustrated in the examples in your writing portfolio example package. Include the name(s) and address(es) of all authors, and date submitted. "Biology lab #1" would not be an informative title, for example.

Abstract

The summary should be two hundred words or less. See the examples in the writing portfolio package.

General intent

An abstract is a concise single paragraph summary of completed work or work in progress. In a minute or less a reader can learn the rationale behind the study, general approach to the problem, pertinent results, and important conclusions or new questions.

Writing an abstract

Write your summary after the rest of the paper is completed. After all, how can you summarize something that is not yet written? Economy of words is important throughout any paper, but especially in an abstract. However, use complete sentences and do not sacrifice readability for brevity. You can keep it concise by wording sentences so that they serve more than one purpose. For example, "In order to learn the role of protein synthesis in early development of the sea urchin, newly fertilized embryos were pulse-labeled with tritiated leucine, to provide a time course of changes in synthetic rate, as measured by total counts per minute (cpm)." This sentence provides the overall question, methods, and type of analysis, all in one sentence. The writer can now go directly to summarizing the results.

Summarize the study, including the following elements in any abstract. Try to keep the first two items to no more than one sentence each.

- Purpose of the study - hypothesis, overall question, objective
- Model organism or system and brief description of the experiment
- Results, including specific data - if the results are quantitative in nature, report quantitative data; results of any statistical analysis should be reported
- Important conclusions or questions that follow from the experiment(s)

Style:

- Single paragraph, and concise
- As a summary of work done, it is always written in past tense
- An abstract should stand on its own, and not refer to any other part of the paper such as a figure or table
- Focus on summarizing results - limit background information to a sentence or two, if absolutely necessary
- What you report in an abstract must be consistent with what you reported in the paper
- Correct spelling, clarity of sentences and phrases, and proper reporting of quantities (proper units, significant figures) are just as important in an abstract as they are anywhere else

Introduction

Your introductions should not exceed two pages (double spaced, typed). See the examples in the writing portfolio package.

General intent

The purpose of an introduction is to acquaint the reader with the rationale behind the work, with the intention of defending it. It places your work in a theoretical context, and enables the reader to understand and appreciate your objectives.

Writing an introduction

The abstract is the only text in a research paper to be written without using paragraphs in order to separate major points. Approaches vary widely, however for our studies the following approach can produce an effective introduction.

- Describe the importance (significance) of the study - why was this worth doing in the first place? Provide a broad context.
- Defend the model - why did you use this particular organism or system? What are its advantages? You might comment on its suitability from a theoretical point of view as well as indicate practical reasons for using it.
- Provide a rationale. State your specific hypothesis(es) or objective(s), and describe the reasoning that led you to select them.
- Very briefly describe the experimental design and how it accomplished the stated objectives.

Style:

- Use past tense except when referring to established facts. After all, the paper will be submitted after all of the work is completed.
- Organize your ideas, making one major point with each paragraph. If you make the four points listed above, you will need a minimum of four paragraphs.
- Present background information only as needed in order support a position. The reader does not want to read everything you know about a subject.
- State the hypothesis/objective precisely - do not oversimplify.
- As always, pay attention to spelling, clarity and appropriateness of sentences and phrases.

Materials and Methods

There is no specific page limit, but a key concept is to keep this section as concise as you possibly can. People will want to read this material selectively. The reader may only be interested in one formula or part of a procedure. Materials and methods may be reported under separate subheadings within this section or can be incorporated together.

General intent

This should be the easiest section to write, but many students misunderstand the purpose. The objective is to document all specialized materials and general procedures, so that another individual may use some or all of the methods in another study or judge the scientific merit of your work. It is not to be a step by step description of everything you did, nor is a methods section a set of

instructions. In particular, it is not supposed to tell a story. By the way, your notebook should contain all of the information that you need for this section.

Writing a Materials and Methods Section

Materials:

- Describe materials separately only if the study is so complicated that it saves space this way.
- Include specialized chemicals, biological materials, and any equipment or supplies that are not commonly found in laboratories.
- Do not include commonly found supplies such as test tubes, pipette tips, beakers, etc., or standard lab equipment such as centrifuges, spectrophotometers, pipettes, etc.
- If use of a specific type of equipment, a specific enzyme, or a culture from a particular supplier is critical to the success of the experiment, then it and the source should be singled out, otherwise no.
- Materials may be reported in a separate paragraph or else they may be identified along with your procedures.
- In biosciences we frequently work with solutions - refer to them by name and describe completely, including concentrations of all reagents, and pH of aqueous solutions, solvent if non-aqueous.

Methods:

- See the examples in the writing portfolio package
- Report the methodology (not details of each procedure that employed the same methodology)
- Describe the methodology completely, including such specifics as temperatures, incubation times, etc.
- To be concise, present methods under headings devoted to specific procedures or groups of procedures
- Generalize - report how procedures were done, not how they were specifically performed on a particular day. For example, report "samples were diluted to a final concentration of 2 mg/ml protein;" don't report that "135 micro liters of sample one was diluted with 330 micro liters of buffer to make the protein concentration 2 mg/ml." Always think about what would be relevant to an investigator at another institution, working on his/her own project.
- If well documented procedures were used, report the procedure by name, perhaps with reference, and that's all. For example, the Bradford assay is well known. You need not report the procedure in full - just that you used a Bradford assay to estimate protein concentration, and identify what you used as a standard. The same is true for the SDS-PAGE method, and many other well known procedures in biology and biochemistry.

Style:

- It is awkward or impossible to use active voice when documenting methods without using first person, which would focus the reader's attention on the investigator rather than the

work. Therefore when writing up the methods most authors use third person passive voice.
- Use normal prose in this and in every other section of the paper – avoid informal lists, and use complete sentences.

What to avoid:

- Materials and methods are not a set of instructions.
- Omit all explanatory information and background - save it for the discussion.
- Omit information that is irrelevant to a third party, such as what color ice bucket you used, or which individual logged in the data.

Results

The page length of this section is set by the amount and types of data to be reported. Continue to be concise, using figures and tables, if appropriate, to present results most effectively. See recommendations for content, below.

General intent

The purpose of a results section is to present and illustrate your findings. Make this section a completely objective report of the results, and save all interpretation for the discussion.

Writing a results section

IMPORTANT: You must clearly distinguish material that would normally be included in a research article from any raw data or other appendix material that would not be published. In fact, such material should not be submitted at all unless requested by the instructor.

Content:

- Summarize your findings in text and illustrate them, if appropriate, with figures and tables.
- In text, describe each of your results, pointing the reader to observations that are most relevant.
- Provide a context, such as by describing the question that was addressed by making a particular observation.
- Describe results of control experiments and include observations that are not presented in a formal figure or table, if appropriate.
- Analyze your data, then prepare the analyzed (converted) data in the form of a figure (graph), table, or in text form.

What to avoid:

- Do not discuss or interpret your results, report background information, or attempt to explain anything.
- Never include raw data or intermediate calculations in a research paper.
- Do not present the same data more than once.

- Text should complement any figures or tables, not repeat the same information.
- Please do not confuse figures with tables - there is a difference.

Style:

- As always, use past tense when you refer to your results, and put everything in a logical order.
- In text, refer to each figure as "figure 1," "figure 2," etc. ; number your tables as well (see the reference text for details)
- Place figures and tables, properly numbered, in order at the end of the report (clearly distinguish them from any other material such as raw data, standard curves, etc.)
- If you prefer, you may place your figures and tables appropriately within the text of your results section.

Figures and tables:

- Either place figures and tables within the text of the result, or include them in the back of the report (following Literature Cited) - do one or the other
- If you place figures and tables at the end of the report, make sure they are clearly distinguished from any attached appendix materials, such as raw data
- Regardless of placement, each figure must be numbered consecutively and complete with caption (caption goes under the figure)
- Regardless of placement, each table must be titled, numbered consecutively and complete with heading (title with description goes above the table)
- Each figure and table must be sufficiently complete that it could stand on its own, separate from text

Discussion

Journal guidelines vary. Space is so valuable in the *Journal of Biological Chemistry*, that authors are asked to restrict discussions to four pages or less, double spaced, typed. That works out to one printed page. While you are learning to write effectively, the limit will be extended to five typed pages. If you practice economy of words, there should be plenty of space to say all that you need to say.

General intent

The objective here is to provide an interpretation of your results and support for all of your conclusions, using evidence from your experiment and generally accepted knowledge, if appropriate. The significance of findings should be clearly described.

Writing a discussion

Interpret your data in the discussion *in appropriate depth*. This means that when you explain a phenomenon you must describe mechanisms that may account for the observation. If your results differ from your expectations, explain why that may have happened. If your results agree, then

describe the theory that the evidence supported. It is never appropriate to simply state that the data agreed with expectations, and let it drop at that.

- Decide if each hypothesis is supported, rejected, or if you cannot make a decision with confidence. Do not simply dismiss a study or part of a study as "inconclusive."
- Research papers are not accepted if the work is incomplete. Draw what conclusions you can based upon the results that you have, and treat the study as a finished work
- You may suggest future directions, such as how the experiment might be modified to accomplish another objective.
- Explain all of your observations as much as possible, *focusing on mechanisms*.
- Decide if the experimental design adequately addressed the hypothesis, and whether or not it was properly controlled.
- Try to offer alternative explanations if reasonable alternatives exist.
- One experiment will not answer an overall question, so keeping the big picture in mind, where do you go next? The best studies open up new avenues of research. What questions remain?
- Recommendations for specific papers will provide additional suggestions.

Style:

- When you refer to information, distinguish data generated by your own studies from published information or from information obtained from other students (verb tense is an important tool for accomplishing that purpose).
- Refer to work done by specific individuals (including yourself) in past tense.
- Refer to generally accepted facts and principles in present tense. For example, "Doofus, in a 1989 survey, *found* that anemia in basset hounds *was correlated* with advanced age. Anemia *is* a condition in which there *is* insufficient hemoglobin in the blood."

The biggest mistake that students make in discussions is to present a superficial interpretation that more or less re-states the results. It is necessary to suggest *why* results came out as they did, focusing on the mechanisms behind the observations.

Literature Cited

Please note that in the introductory laboratory course, you will not be required to properly document sources of all of your information. One reason is that your major source of information is this website, and websites are inappropriate as primary sources. Second, it is problematic to provide a hundred students with equal access to potential reference materials. You may nevertheless find outside sources, and you should cite any articles that the instructor provides or that you find for yourself.

List all literature cited in your paper, in alphabetical order, by first author. In a proper research paper, only primary literature is used (original research articles authored by the original investigators). Be cautious about using web sites as references - anyone can put just about anything on a web site, and you have no sure way of knowing if it is truth or fiction. If you are citing an on

line journal, use the journal citation (name, volume, year, page numbers). Some of your papers may not require references, and if that is the case simply state that "no references were consulted."

*http://www.ruf.rice.edu/~bioslabs/tools/report/reportform.html

Additional Useful Tips & Links

Resources for Writing in Biology

- **A Guide to Writing in the Biological Sciences**

http://classweb.gmu.edu/biologyresources/writingguide/ScientificPaper.htm

- **Examples of Student Papers Written in the Biological Sciences**

http://classweb.gmu.edu/biologyresources/writingguide/Students.htm

- **Practical Tips for Scientific Writing**

http://writing2.richmond.edu/training/project/biology/biology.html

- **Alverno Biology Department's Student Writing Guide**

http://depts.alverno.edu/nsmt/writing.htm

- **Marquette University's Guide to Writing in Biology Courses**

http://www.marquette.edu/wac/departmental/MarquetteUniversityWritinginBiologyCourses.shtml

- **Writing Biology Lab Reports from Westfield State University**

http://biology.wsc.ma.edu/wscwg/biology/labrep.html

- **Writing Biology Lab Reports**

http://writing2.richmond.edu/training/project/biology/biology.html

- **Advice for Writing in the Biological Sciences for Non-Majors from Dartmouth University**

http://biology.wsc.ma.edu/wscwg/biology/labrep.html

General Guide to Attending to Study from Dartmouth University (references Joseph Williams' Style: *The Basics of Clarity and Grace*, a valuable book for any college writer, in my estimation: Judy; also references *Elements of Style* by William Strunk, Jr.*;* the link to this guide should be kept on all students' computer lists of helpful links for writing*)*

http://www.dartmouth.edu/~writing/materials/student/ac_paper/style.shtml

- **Dickinson College's Guide to Writing a Scientific Paper per the Biology Paper**

http://alpha.dickinson.edu/departments/biol/BioWritingGuide/biogdline.html

- **Hamilton College's Guide to Writing Biology Lab Reports**

http://www.hamilton.edu/writing/biolab.html

- **Sample Student Biology Lab Report for an Introductory Course (written in 1995)**

http://www.hamilton.edu/academics/resource/wc/Sample_Bio.PDF

- **Expectations for Writing in Biology** (provides a list of criteria and definitions) from Clarion's Writing Outcomes for Biology Students

http://www.clarion.edu/gened/BiologyExpectations.pdf

Resources for Writing in Chemistry

- American Chemical Society Publications

http://pubs.acs.org/about.html

This site provides links to journals in the field of chemistry (such as Chemical Reviews and Journal of the American Chemical Society). Clicking on a journal title allows you to browse through recent issues or search that journal for information on a particular topic.

- American Chemical Society

http://www.chemistry.org/portal/a/c/s/1/home.html

The website of the American Chemical Society offers a great deal of information for chemistry students, including an interactive Periodic Table of the Elements. The Educators and Students page allows students to browse recent articles and offers a list of internet resources for undergraduate and graduate students.

- Writing at Colorado State University: Writing Guide for Science

http://writing.colostate.edu/references/processes/science/

The information on this page concerns general science writing, offering information on writing in the scientific format and achieving the scientific voice. The organization of the site makes it very easy to navigate through a great deal of information.

- Lynchburg College in Virginia: Writing in Chemistry

http://www.lynchburg.edu/writcntr/guide/CITATION/chemistry.htm

This site provides a list of the characteristics of good writing in chemistry, with a thorough explanation of each, as well as a list of "Hints and Suggestions for Written Work in Chemistry." These guidelines offer a solid introduction to writing in the field.

- Haverford College Chemistry Department: General Guidelines for Written Reports

http://www.haverford.edu/chem/dept/writingguidelines.pdf

This document (in PDF form) offers advice specific to writing in chemistry, such how to effectively incorporate chemical structures, tables and graphs, and equations into the body of the paper.

- Swarthmore College: A Guide to Writing in Chemistry

http://www.swarthmore.edu/Humanities/wa/writingInTheDisciplines/SpecificDisciplines/chemistry.htm

This site offers very detailed information about writing in chemistry. Various components of this page include a basic explanation of the nature of a chemistry paper, explanation of two forms of writing assignments in chemistry (lab reports and abstracts), an outline of discipline-specific strategies and some strategies for avoiding common mistakes made in chemistry writing.

- Oregon State University Chemistry Department: Writing Guide for Chemistry

http://www.chem.orst.edu/writing/WritingGuide2000.htm

This site provides a great deal of information on both chemistry-specific writing guidelines and general writing recommendations.

- Georgetown University: Guidelines for Scientific Writing

http://www.physics.georgetown.edu/~urbach/phy300/sciwriting.html

This handout offers ten guidelines to help students with various aspects of scientific writing. Though this guide comes from the Physics Department at Georgetown University, the information provided deals with scientific writing in general, and would therefore be useful to writers in Chemistry. The handout is based on advice distributed by Professor J. Wilkins of Ohio State University and the Research Corporation and has been assembled by J. Freericks, A. Liu and J. S. Urbach of Georgetown University.

- The American Chemical Society (ACS) Style Guide.

http://www.oup-usa.org/sc/0841234620/0841234620_1.html

The online edition of the ACS Style Guide is very easy to navigate, allowing you to browse through the chapters to find the specific information you need. Perhaps the most useful chapters would be the following: Getting Started, Writing Style and Word Usage, and Components of a Paper.